DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-15

HABITAT DEVELOPMENT FIELD INVESTIGATIONS BOLIVAR PENINSULA, MARSH AND UPLAND HABITAT DEVELOPMENT SITE, GALVESTON BAY, TEXAS

SUMMARY REPORT

by

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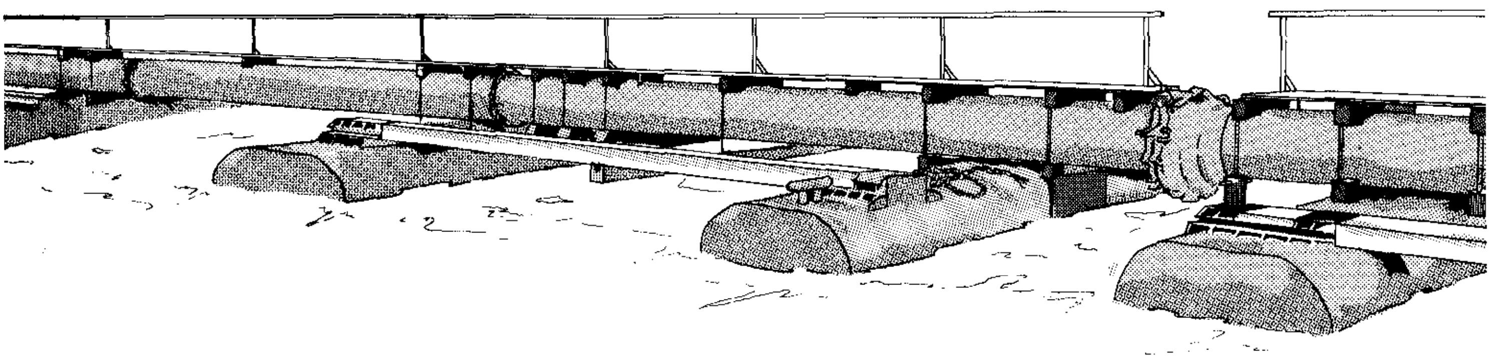

Prepared for Office, Chief of Engineers, U. S. Army
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Under DMRP Work Unit No. 4A13K

HABITAT DEVELOPMENT FIELD INVESTIGATIONS, BOLIVAR PENINSULA
MARSH AND UPLAND HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

Appendix A: Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics

Appendix B: Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry

Appendix C: Baseline Inventory of Aquatic Biota

Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESEV

30 September 1978

SUBJECT: Transmittal of Technical Report D-78-15

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of one of a series of research efforts (work units) undertaken as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4A was part of the Habitat Development Project (HDP) and had as its objective the development and testing of the environmental and economic feasibility of using dredged material as a substrate for marsh development.

2. Marsh development using dredged material was investigated by the HDP under both laboratory and field conditions. This report, "Habitat Development Field Investigations, Bolivar Peninsula Marsh and Upland Habitat Development Site, Galveston Bay, Texas; Summary Report" (Work Unit 4A13K), summarizes the activities that occurred during marsh and upland habitat development studies in Galveston County, Texas, between 1975 and 1977. A general discussion of the engineering and biological aspects of the research is presented. The reader is referred to Appendices A through D to this report for a more detailed discussion.

3. A total of nine marsh development sites were selected and designed by the HDP at various locations throughout the United States. Six sites were subsequently constructed. Those, in addition to Bolivar Peninsula, include: Windmill Point on the James River, Virginia (4A11); Buttermilk Sound, Atlantic Intracoastal Waterway, Georgia (4A12); Apalachicola Bay, Apalachicola, Florida (4A19); Pond #3, San Francisco Bay, California (4A18); and Miller Sands, Columbia River, Oregon (4B05). Detailed design for marsh restoration at Dyke Marsh on the Potomac River (4A17) was completed, but project construction was delayed in the coordination process. Marsh development at Branford Harbor, Connecticut (4A10) and Grays Harbor, Washington (4A14) was terminated because of local opposition and engineering infeasibility, respectively. Upland habitat was developed at two sites in addition to Bolivar Peninsula: Miller Sands, Oregon (4B05) and Nott Island, Connecticut River, Connecticut (4B04).

4. Evaluated together, the field site studies plus ancillary field and laboratory evaluations conducted in Task 4A establish and define the range of conditions under which marsh habitat development is feasible.

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Data presented in the research reports prepared under this task will be synthesized in the technical reports entitled "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations" (2A08), and "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation" (4A24).

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Bolivar Peninsula	Habitat development	Waste disposal sites
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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*
A 2-1/2-year field investigation was conducted at Bolivar Peninsula, Galveston Bay, Texas, to test the feasibility and impact of developing marsh and upland habitats on dredged material. This report summarizes baseline information derived before habitat development operations and results of postdevelopment operations.

Two marsh grass species and nine upland plant species including trees, shrubs, and grasses were planted in test plots on a dredged material site (Continued)

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20. ABSTRACT (Continued).

lying between the Gulf Intracoastal Waterway and Galveston Bay. Tests were conducted to measure plant survival and performance in response to different fertilizer treatments and planting methods. Plantings of the marsh grasses were made within an intertidal area protected from wave energies by a sandbag dike. Prior to and during plant development, information was collected to document changes in fish and wildlife communities.

Plantings were successful in both and marsh and upland. Marsh grasses surviving and performing well included smooth cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass (*Spartina patens*). Upland plants demonstrating good survival and growth were live oak (*Quercus virginiana*), wax myrtle (*Myrica cerifera*), winged sumac (*Rhus copallina*), bitter panicum grass (*Panicum amarum*), and coastal bermuda grass (*Cynodon dactylon* var *alecia*).

Components of the habitat development site, consisting of the planted vegetation and sandbag dike, attracted insects, aquatic organisms, and birds. As the plants developed, the numbers of shore insects, mainly dipterans and beetles, increased greatly in the intertidal study area. Shorebirds associated with marshes moved onto the site and increased in density. The abundance of benthos was 1.5 times greater inside the diked area than outside; within the diked area, the benthos in planted areas was 1.5 times as abundant as the benthos in bare areas.

After less than a year of development, the site provided heterogeneous habitats which tended to support greater use by fish and benthos than is generally associated with sandy shores along Bolivar Peninsula. The field investigation indicated that habitat development is a feasible dredged material disposal alternative.

PREFACE

This report presents a summary of results of a 2-½-year field investigation (March 1975 to November 1977) of the feasibility and impact of developing marsh and upland habitat on dredged material at a site located at Bolivar Peninsula, Galveston Bay, Texas. The report summarizes baseline information derived before habitat development operations and results of post-development operations. The investigation was conducted as part of the Corps of Engineers' Dredged Material Research Program (DMRP). The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army, and was managed by the Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

The investigation involved two interagency agreements and two contracts. Interagency agreements were made between WES and the U. S. Geological Survey at Austin, Texas and the National Marine Fisheries Service, Gulf Coastal Fisheries Center, Galveston, Texas. Two contracts were made between WES and Texas A&M University and Agricultural Experiment Station, College Station, Texas. Reports resulting from these agreements and contracts appear as the following appendices to this report: Appendix A (Lunz et al. 1978), Appendix B (Dodd et al. 1978), Appendix C (Lyon and Baxter 1978), and Appendix D (Webb et al. 1978).

This investigation could not have been completed without the substantial engineering and construction support provided by the U. S. Army Engineer District, Galveston. The District performed tasks involving site preparation, dike construction and maintenance, fence construction, and logistical support to WES. District Engineers during the period of this investigation were COL Don S. McCoy, CE, and COL Jon C. C. Vanden Bosch, CE.

Preliminary planning of the experimental design and research procedures used in the investigation was accomplished by the staff of the Natural Resources Development Branch (NRDB), Environmental Resources Division of EL. These personnel were Messrs. E. P. Peloquin,

Hollis H. Allen, and John D. Lunz and Drs. J. Scott Boyce and Judith E. Unsicker.

This report was written primarily by the staff of the NRDB. The plants and soils aspects were written by Mr. Hollis H. Allen and Dr. R. B. Wells; the aquatic biology section was written by Dr. Robert J. Diaz and Mr. Ellis J. Clairain, Jr.; and the wildlife section was written by Ms. L. Jean Hunt. Significant contributions were made to the engineering and construction section of the report by Mr. Alfred W. Ford of the Environmental Engineering Division of EL and Mr. Dolan Dunn of the Galveston District who furnished much of the engineering and construction information. Editing was done by Mr. Hollis H. Allen, Ms. Mary K. Vincent, and Dr. Richard A. Cole (Michigan State University and NRDB). Editorial supervision was provided by Ms. Dorothy P. Booth.

The project was under the general supervision of Dr. H. K. Smith, Project Manager, Habitat Development Project of the DMRP; Dr. C. J. Kirby, Chief, Environmental Resources Division; and Dr. John Harrison, Chief, EL.

Commanders and Directors of WES during the period of this study were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS
BOLIVAR PENINSULA MARSH AND UPLAND
HABITAT DEVELOPMENT SITE
GALVESTON BAY, TEXAS

SUMMARY REPORT

PART I: INTRODUCTION

1. The U. S. Army Corps of Engineers dredges large volumes of material to develop and maintain the nation's navigable waterways and harbors. This material must be disposed in a cost-effective, environmentally compatible manner. The Corps currently maintains over 30,600 km of waterways and about 1,000 harbors (Boyd et al. 1972). From 1969 to 1972 about 290.5 million cu m were dredged annually, enough to cover 3,108 sq km with 0.91 m of material. Maintenance dredging in the Galveston District alone, containing the research site with which this report is concerned, amounts to nearly 37 million cu m annually, the second largest of all district dredging efforts and 13 percent of all dredging activity.

2. Much of the dredged material in the Galveston District is dumped into the open sea when this is economical and environmentally sound. But because of cost limitations, much material is disposed in shallow water or on land near the dredging project. In many situations it may be possible to use dredged material for various purposes to mitigate undesirable environmental effects. The Dredged Material Research Program was initiated in 1973 at the Waterways Experiment Station with one of its objectives being the development of alternative uses of dredged material. One possible use of dredged material is development of habitat for desirable plants and animals. To investigate this possibility in the research program, several sites were selected at representative dredging projects in the United States. Because of the amount of dredging conducted in the Galveston District and its geographical location, the Bolivar Site was chosen for site representation.

3. The purpose of this report is to summarize and discuss results of studies on the use of dredged material for developing intertidal marsh habitat and upland habitat above high tide on Bolivar Peninsula about 16 km east of Galveston, Texas. Several basic research objectives were defined for study:

- a. Document planning, design, construction and subsequent physical changes in the substrate and engineered structures used for habitat development.
- b. Develop appropriate planting and cultural practices.
- c. Relate the productivity and nutrient content of selected plant species grown on dredged material to the varying chemical and physical properties of the site.
- d. Relate animal use to the physical characteristics of the dredged material and vascular plants.
- e. Describe the changes, if any, in water quality, sediments, hydrography and aquatic and terrestrial biota following the disposal of dredged material and site development.
- f. Document the monetary costs for various aspects of the project such as site development, research and total costs.
- g. Document the constraints of social and political institutions in the construction of the habitat development site.

4. The scope of this study included an investigation of conditions at the Bolivar Peninsula site before the commencement of habitat development operations as well as afterwards. Baseline data on water quality, sediments, hydrography, and aquatic and terrestrial biota were taken for two reasons: a) to aid in the planning of habitat development and b) to describe the changes in the above factors following dredged material manipulation and site development. Baseline conditions of the site are reported in Appendices A through C to this report.

5. It should be noted that baseline data were collected from an area 305 m to the west of where habitat development actually occurred. Because of an unanticipated interruption in the Galveston District's dredging schedule, fresh dredged material could not be disposed at

the original site when it was needed. Therefore, the habitat was developed on about two-year-old dredged material to the east of the original site. This move did not constitute a great change in baseline conditions between the two sites since both sites consisted of similar dredged material and had similar physical and biological attributes.

PART II: SITE DESCRIPTION

Geography

6. Several coastal sites in Texas were inspected for potential habitat development during spring 1974. The site at Bolivar Peninsula (Figure 1) was selected in spring 1975 as generally representative of most of the disposal areas along the Texas coast. The site is located within the boundaries of the High Island to Galveston Bay Project, a 64-km portion of the Gulf Intracoastal Waterway. The waterway is maintained by hydraulic pipeline dredging and about 764,000 cu m annually are deposited in disposal areas along the waterway (U. S. Army Corps of Engineers 1974). The disposal area selected for study borders the waterway at km 552. The experimental site consists of 7.3 ha that ranges in elevation between -0.06 and +3.05 m msl (U. S. Army Corps of Engineers 1975).

7. Bolivar Peninsula is an offshore sandbar near the eastern end of a chain of barrier islands extending nearly 960 km along the Mexican and Texas coasts (Lankford and Rehkemper 1969). The peninsula is maintained by littoral transport and occasional transport of coarse sediments by seawater which washes over the barrier into Galveston Bay. Soils on the experimental area are comprised of the Harris, Veston, and Galveston soil series (Godfrey et al. 1973). Saline clays and loams occur in nearby marshes and sands occupy the beaches. Heavy marsh soils generally are overlain by peat (Lay and O'Neil 1942). The principal land uses of the peninsula are ranching and petroleum drilling. Feral goats freely roam in the area.

Meteorology and Hydrology

8. The climate is warm and humid, moderated by the Gulf of Mexico. Average annual precipitation is 106.2 cm and mean temperatures range from a daily low of 4 deg C in winter to a daily high of 34 deg C in summer (Fisher et al. 1972). Rainfall annually exceeds evaporation

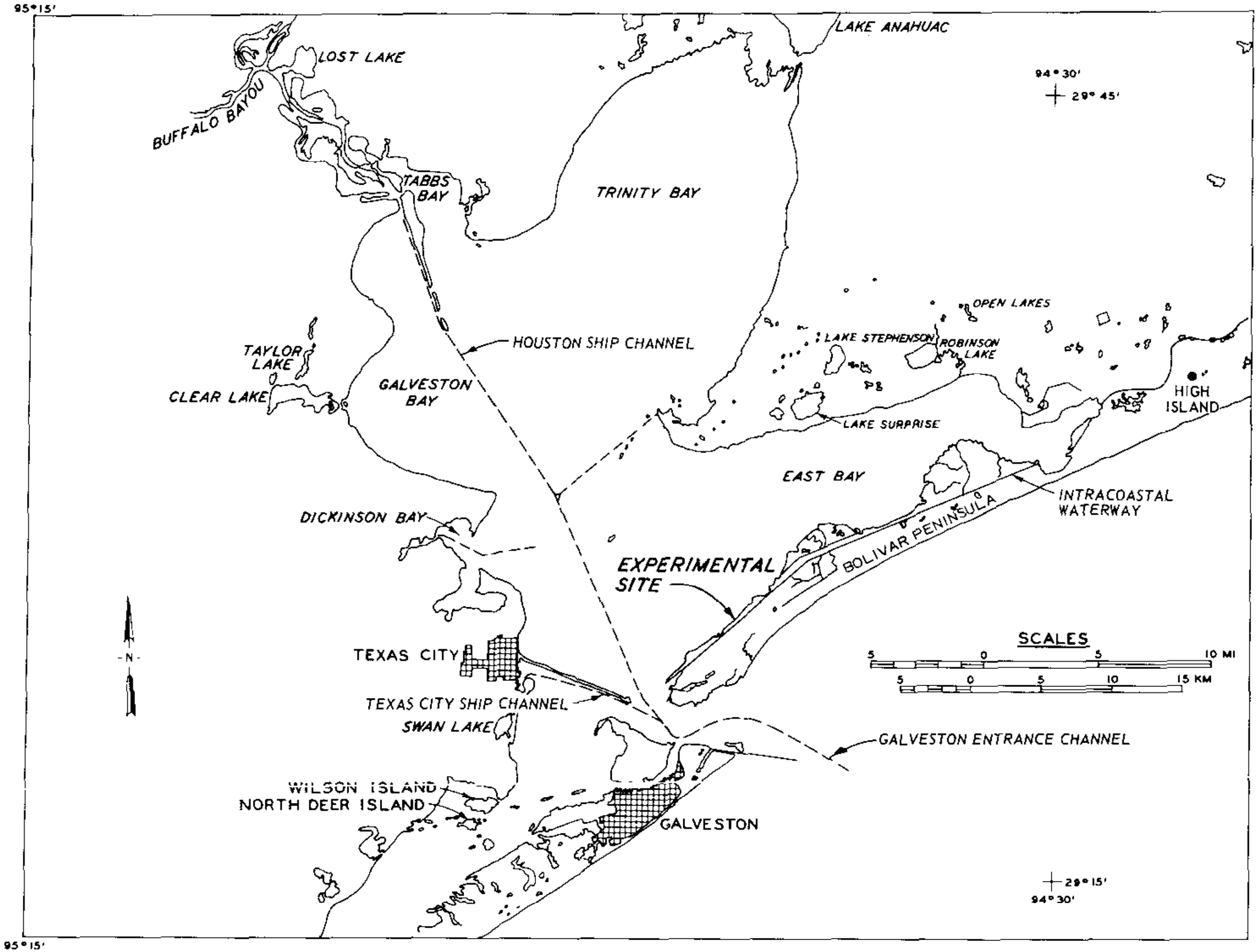


Figure 1. Location of Bolivar Peninsula habitat development site

and plant transpiration by 13 to 20 cm, which is a larger difference than coastal areas farther west. This excess precipitation contributes to groundwater storage and affects the boundary between fresh and saline waters in beach and marsh soils. Prevailing winds from March through November are southerly and average 17.6 kph (Lankford and Rehkemper 1969). Short-lived but strong northerly winds averaging 64 kph often occur in winter months (Fisher et al. 1972).

9. Water levels for 13 years of record (Lunz et al. 1978) were between -0.37 and +0.85 m msl 98 percent of the time. These water levels are determined largely by wind speed and direction. Changes in water levels occur when wind speeds become greater than 21 kph. This happens about 45 percent of the days each year. West and northwest winds cause the greatest change in water level for the least wind. Winds of 21 to 32 kph from any direction cause changes of 0.15 to 0.30 m. The probability of a hurricane occurring in any particular year is high, 23 percent (Henry et al. 1975). Storm surges associated with hurricanes may range between 4.6 to 6.1 m above mean sea level, potentially capable of completely inundating the upland and marsh experimental areas.

Plants and Animals

10. Six natural plant associations were identified on the site by Dodd et al. (1978) as communities dominated by: (1) bluestem grass (*Andropogan perangustatus*), (2) saltmeadow cordgrass (*Spartina patens*), (3) seashore dropseed (*Sporobolus virginicus*), (4) Drummond sesbania (*Sesbania drummondii*) and mixed grasses, (5) lemon beebalm (*Monarda citriodora*), and (6) smooth cordgrass (*Spartina alterniflora*). The area was dominated by bluestem grass and saltmeadow cordgrass communities, which, together, occupied 62 percent of the area.

11. Red-winged blackbirds (*Agelaius phoeniceus*), eastern meadowlarks (*Sturnella magna*), common grackles (*Quiscalus quiscula*), and great-tailed grackles (*Q. mexicanus*) were the most commonly seen birds of the upland. Laughing gulls (*Larus atricilla*) and Caspian terns

(Sterna caspia) frequented the shoreline. The most common mammals were armadillos (Dasypus novemicinctus), raccoons (Procyon lotor), swamp rabbits (Sylvilagus aquaticus), cotton rats (Sigmodon hispidus), and feral goats (Capra hircus). Common land invertebrates were grasshoppers, land snails, fiddler crabs (Uca pugnax), and the tiger beetle (Cicindelidae).

12. There were no submerged aquatic plant communities at the site (Lyon and Baxter 1978). Associated zooplankton were mostly barnacle larvae and copepods. Among the abundant larger invertebrates were white shrimp (Penaeus setiferus) and several species of marine worms (Polychaeta). Extensive oyster beds occur in Galveston Bay but the nearest was 5.9 km from the site (Lyon and Baxter 1978).

PART III: ENGINEERING AND CONSTRUCTION

Methods and Materials

Site preparation

13. The plans for habitat development as mentioned in the introduction, originally specified that substrate be composed of freshly deposited dredged material, but instead, because of an interruption in the dredging schedule, habitat was developed on a two-year old disposal area 305 m east of the original site. The substrate had been hydraulically deposited over older deposits of dredged material. Because the material had been routinely deposited without care for elevational uniformity, it required landscaping to meet experimental specifications. All existing vegetation was cleared from the site before experimentation. A dike of sandbags was constructed to dissipate wave energies within the intertidal zone at the experimental site and a fence was built to exclude goats, rabbits, and other potentially destructive animals.

14. The site design, size, and construction specifications are illustrated in Figure 2. The site was surveyed and graded to provide space for two main experimental plantings, an intertidal area for marsh plants, and an area above tide for upland plants. Based on estimated tolerances of the experimental plants to inundation, the intertidal area was graded to a prespecified slope of 0.67 percent ranging between -0.15 to +0.64 m msl. All of the area inside the fence was graded including the area outside the dike of sandbags. The upland area was not precisely graded but was back-dragged to level mounds and depressions. This was done above +0.64 m msl, considered to be the upper level of the intertidal experimental area. A contract was awarded for the land preparation on 29 January 1976, and the job was completed on 5 March 1976.

Dike design and construction

15. Based on hydrodynamic data developed by the U. S. Geological Survey, marsh development was not expected to succeed without

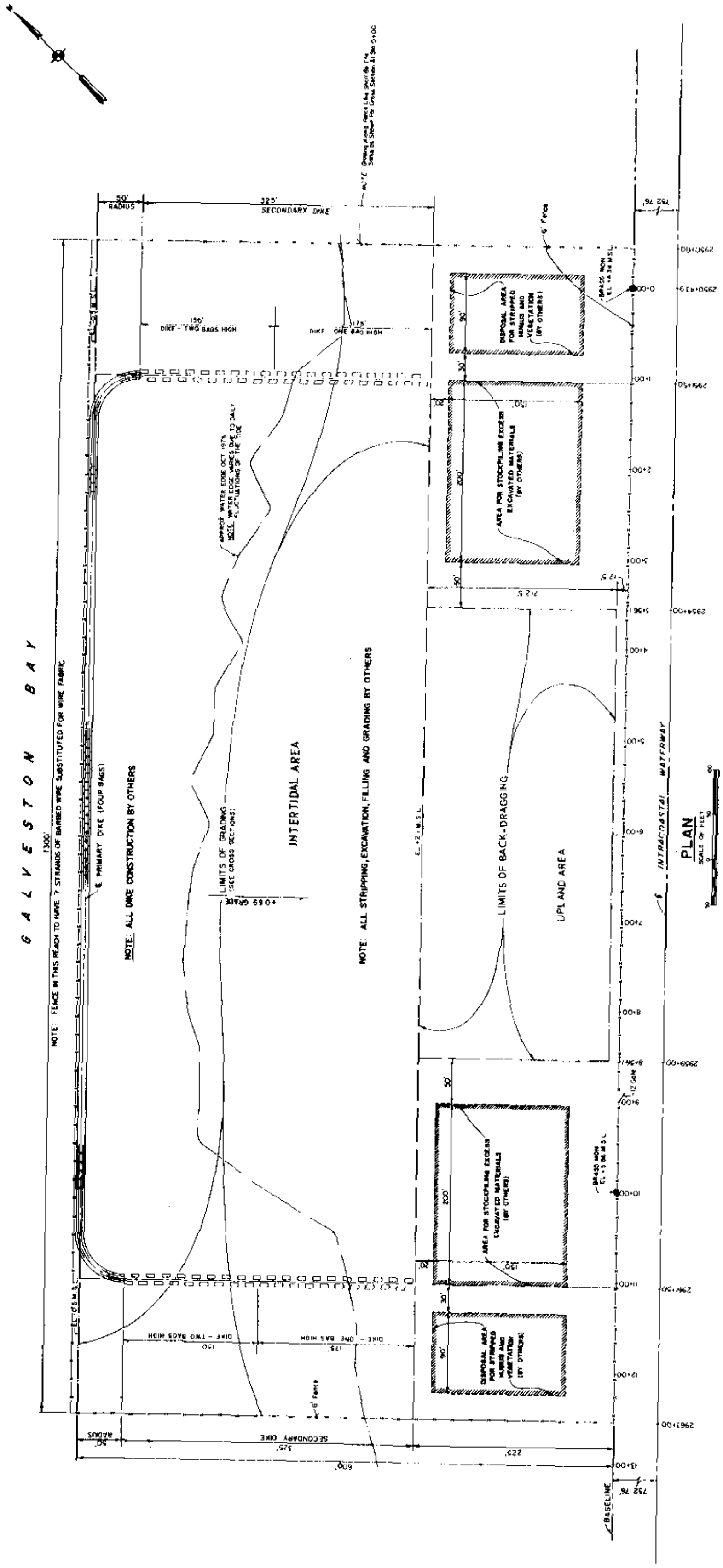


Figure 2. Site design, size, and construction specifications

protection from the wave energies released on the site. To dissipate the energy, a primary dike was constructed offshore (Figure 2) with woven-nylon, plastic-coated sandbags. Each filled bag weighed about 3,175 kg and had dimensions of 1.37 by 2.90 by 0.46 m. Bags were also used to build a secondary dike, which protected the flanks of the experimental areas. Spaces were left between sandbags in these dikes to allow free tidal exchange in the experimental area. See Figure 3 for dimensions and layout of the sandbags.

16. The dikes were constructed by personnel of the Galveston District between February and June 1976. The work began with the secondary dike to the northeast and progressed around the perimeter, finishing with the secondary dike to the southwest. Figures 4 and 5 show aspects of the work while it was in progress. The dike was built at a rate of 15 to 20 bags per day and 1,000 bags were placed in total. Each bag was filled in place (Figure 6) with a slurry of sand and water. The pervious fabric in the bags passed the water and retained the sand.

Fence construction

17. A fence was constructed around the outside perimeter to exclude goats and other animals that could eat or trample the experimental plantings. The Galveston District prepared specifications for fence construction (Figure 7) and awarded a contract in March 1976 for its completion. The contractor failed to comply with the specifications clearly identified for construction in the inundated areas of the site, so the contract was modified and personnel at the Galveston District completed the job.

18. That part of the job completed in water was accomplished with specialized methods and equipment. The 3.05-m posts were hydraulically driven into the sandy substrate with a jet pump and hose. A jet of water was used to erode away the sand surrounding the base of the post, which sank into the resulting cavity. The holes around the posts were filled with sand, and the posts were left to settle tightly. It took a three-man crew 5 work weeks to build the 579-m section in water. The job was completed in October 1976.

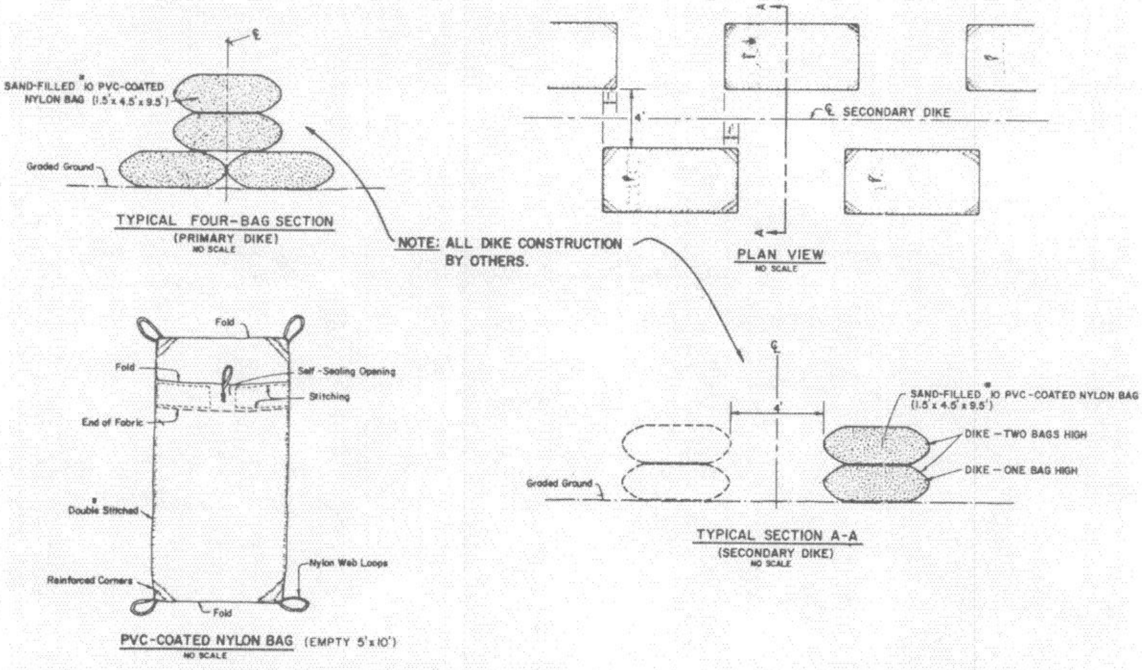


Figure 3. Dimensions and layout of sandbags

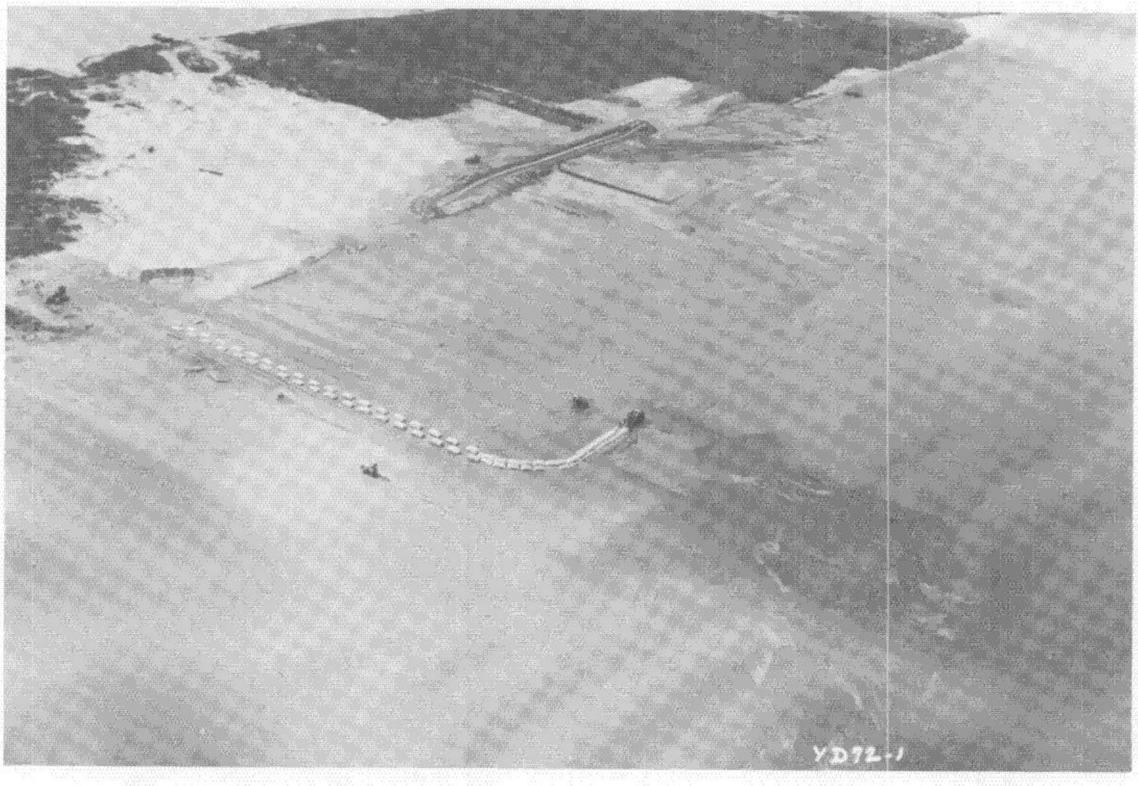
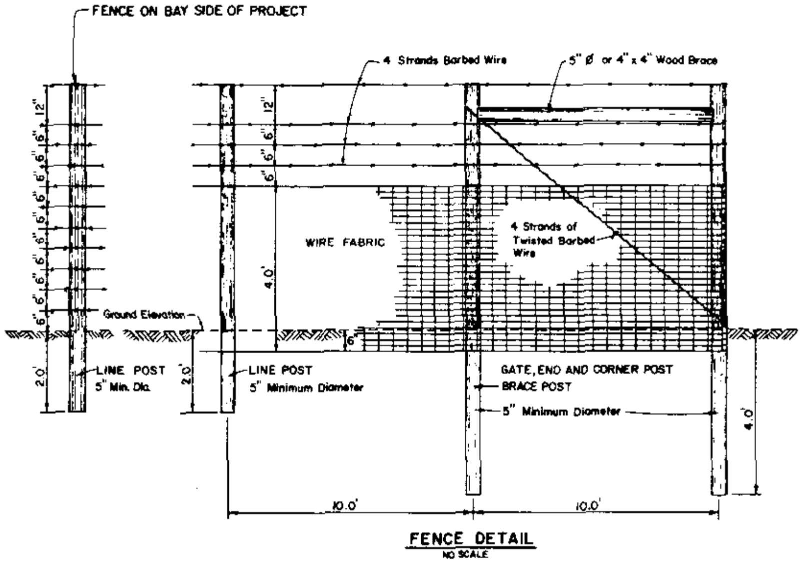


Figure 4. Site development activities showing grading and primary and secondary dike construction

Figure 5. Dike construction showing equipment in operation

Figure 6. Sandbags being filled in place with slurry of sand and water



FENCE NOTES:

1. MAXIMUM LENGTH OF UNBRACED FENCE SHALL NOT EXCEED 500 FEET. BRACING POST SHALL BE EQUIVALENT TO CORNER POST AND SHALL BE BRACED EACH SIDE WITH DIAGONAL BRACES SIMILAR TO CORNER BRACING.
2. ALL METAL SHALL BE HOT-DIP GALVANIZED.
3. WIRE SHALL BE FASTENED TO WOOD POST WITH GALVANIZED STAPLES MADE OF NO.9 WIRE.
4. FENCE AND GATES SHALL BE FURNISHED COMPLETE WITH ALL NECESSARY FITTINGS.
5. WIRE FABRIC TO BE NO. 12.5 GAGE WIRE, WELDED IN 2 VERTICAL-4 HORIZONTAL INCH MESH, FOUR FEET IN HEIGHT.
6. BARBED WIRE SHALL BE NO. 12.5 GAGE, TWO POINT, MEETING FEDERAL SPEC. RR-F-221 FOR ZINC COATING, SPACED AS SHOWN ON FENCE DETAIL.
7. CORNER POST SHALL BE INSTALLED AT ALL CORNERS.
8. CORNER AND BRACE POSTS SHALL BE NOTCHED AND NAILED WHERE WOODEN BRACE BUTTS POST.
9. LINE POSTS SHALL BE 8 FEET LONG, 5 INCH DIAMETER, CORNER AND BRACE POSTS SHALL BE 10 FEET LONG, 5 INCH DIAMETER, PEELED, PENTA TREATED, EXCEPT AS OTHERWISE NOTED.
10. GATE SHALL BE 12 FEET WIDE 6 FEET HIGH WITH NO. 12.5 GAGE WIRE, 2 VERT.—4 HORIZ. INCH MESH, 6 FEET IN HEIGHT. GATE SHALL BE FRAMED WITH 1 3/8 INCH O.D. GALVANIZED PIPE.

Figure 7. Fence design and specifications

Results and Discussion

Grading and clearing

19. Grading and clearing produced a satisfactory environment for experimentation. Erosion rates were not uniform on the site following grading so elevations tended to vary more with time. All machinery used for grading proved effective but a light bulldozer proved advantageous in the intertidal areas while a heavier bulldozer was more suitable for upland conditions. A rubber-tired, front-end loader performed well moving material over the site.

Dike construction

20. The dikes afforded the protection needed at the site but severe maintenance problems arose before the dike was completed. At some places along the primary dike, filled sandbags began to sink rapidly and, in some cases, lose sand. Two modes of dike failure occurred: channel development beneath the point of two adjoining bags and substrate scouring along the face of the dike. It was soon realized that the bags would require periodic refilling to make up for leaching through the fabric. Figure 8 depicts a typical dike failure. In an attempt to prevent scour in the dike remaining to be built, filter cloth was placed under the sandbags. In addition, four sandbags were used in the base layer rather than two. Smaller sandbags were used to repair breaches in the completed dike. Regardless of these efforts, dike deterioration continued to be a problem throughout the study period because of scour.

21. Ultimately, half of the primary dike was placed on filter cloth and the base was widened from two to four bags. Even though half of the dike was not stabilized, the experimental area was protected from wave action during the study period but not without costly effort. High water levels in the bay often delayed dike construction. Placing sandbags under water required special care to assure that the bags were properly positioned and secured. Because the salt water was corrosive, mechanical breakdowns were common.

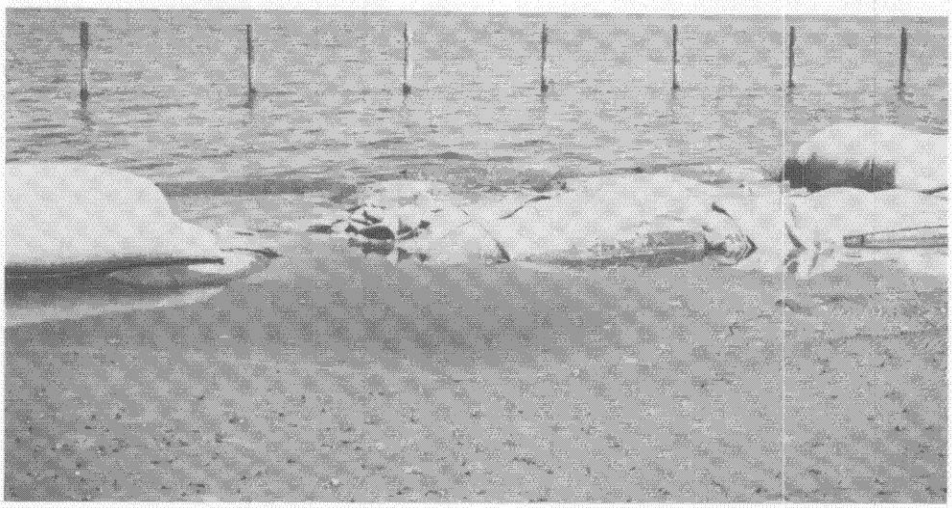


Figure 8. Typical failure of primary dike

Recommendations for dike protection

22. It is recommended that in future construction of protective dikes, a representative section of test dike be built before the main job is initiated. A small test section was constructed at the Bolivar site, but it was too small to identify the erosion problems that were encountered later. Future dikes of this type in this area should be built on filter cloth to reduce the effects of erosion. It is noteworthy that where filter cloth was placed under the base layer of sandbags no maintenance was required. An alternative design, which might reduce erosion effects even further, would be the construction of two parallel lengths of alternating 15-m lengths of dike separated by 9 to 12 m. This design would protect the site and also allow numerous water exchange openings that would reduce scouring along the faces of the dike.

Fence construction

23. The fence was completed without complication after the construction contract was modified and the Galveston District assumed full construction responsibility. The fence excluded goats but rabbits were able to pass through the 6 x 13 strands per m wire mesh. To exclude rabbits, chicken wire was placed at the base of the fence by personnel from Texas A&M University.

Costs of site development

24. Costs are itemized in Table 1. These costs are generally inflated because of the research specifications required. More was spent on planning, design, and construction than would have resulted without the research goals in mind. The dike cost more than anticipated because of maintenance requirements. The use of filter cloth should significantly reduce maintenance costs. Costs of plant procurement and planting were not documented at the Bolivar site but they would be higher than for routine habitat development because of the complex experimental design used. Zarudsky (1975) reports that planting smooth cordgrass on dredged material in Long Island cost $5,565/ha for plant procurement, planting labor, fertilizer and plant shipment. Woodhouse et al. (1972) found that procurement and hand transplanting

of smooth cordgrass required 134 man-hours/ha in North Carolina.

Summary and Conclusions

25. Dike construction and other site development operations probably were necessary at Bolivar to establish the marsh habitat. However, less expersive techniques for barrier construction should be considered for future projects. Where reasonable, the use of dredged material to build a barrier should be considered for areas with intense wave energies. Fence construction also seemed to be absolutely necessary and may be required in any area where large grazing animals are common.

PART IV: PLANTS AND SOILS

Methods and Materials

Intertidal zone

26. Experimental design. The 7.3-ha site was divided into intertidal and upland zones (Figure 9). Each zone had its own experimental design (Figure 10). The intertidal zone was divided equally into three elevational tiers, tiers 1, 2, and 3 (Figure 10). The percentages of time that these tiers were inundated by tidal water from 1 February to 31 August 1977, the majority of the growing season, was 80 to 93 percent for the lowest tier (tier 1), 9 to 80 percent for the intermediate tier (tier 2), and 1 to 9 percent for the upper tier (tier 3). Each elevational tier was divided into three blocks of 30 plots each. The 6 by 10-m plots were randomized for experimental treatment according to the schedule provided in Table 2. Within each block, 10 plots each were planted with smooth cordgrass, saltmeadow cordgrass, or left unplanted. For each 10 plots, five were sprigged and five were seeded. Each of these five plots was fertilized in a different manner, including no fertilization at all. The 10 unplanted plots were also split into two sets of five fertilization treatments. In total, three plots in each elevational tier were treated identically for each of the 30 different treatment combinations. This design was later modified by dividing some plots in half in order to refine the analysis of elevational effects on plant performance and to analyze the effect of different planting times on sprig growth of smooth cordgrass. Details of this modification can be found in Webb et al. (1978).

27. In the intertidal zone, two pairs of long, planted and unplanted plots were established outside the dike and two pairs were established inside the dike but outside of the monotypic marsh plots (Figure 9). These plots were sprigged with alternating rows of smooth cordgrass and saltmeadow cordgrass but were not fertilized. They provided a qualitative evaluation of dike effects on plant survival and growth.

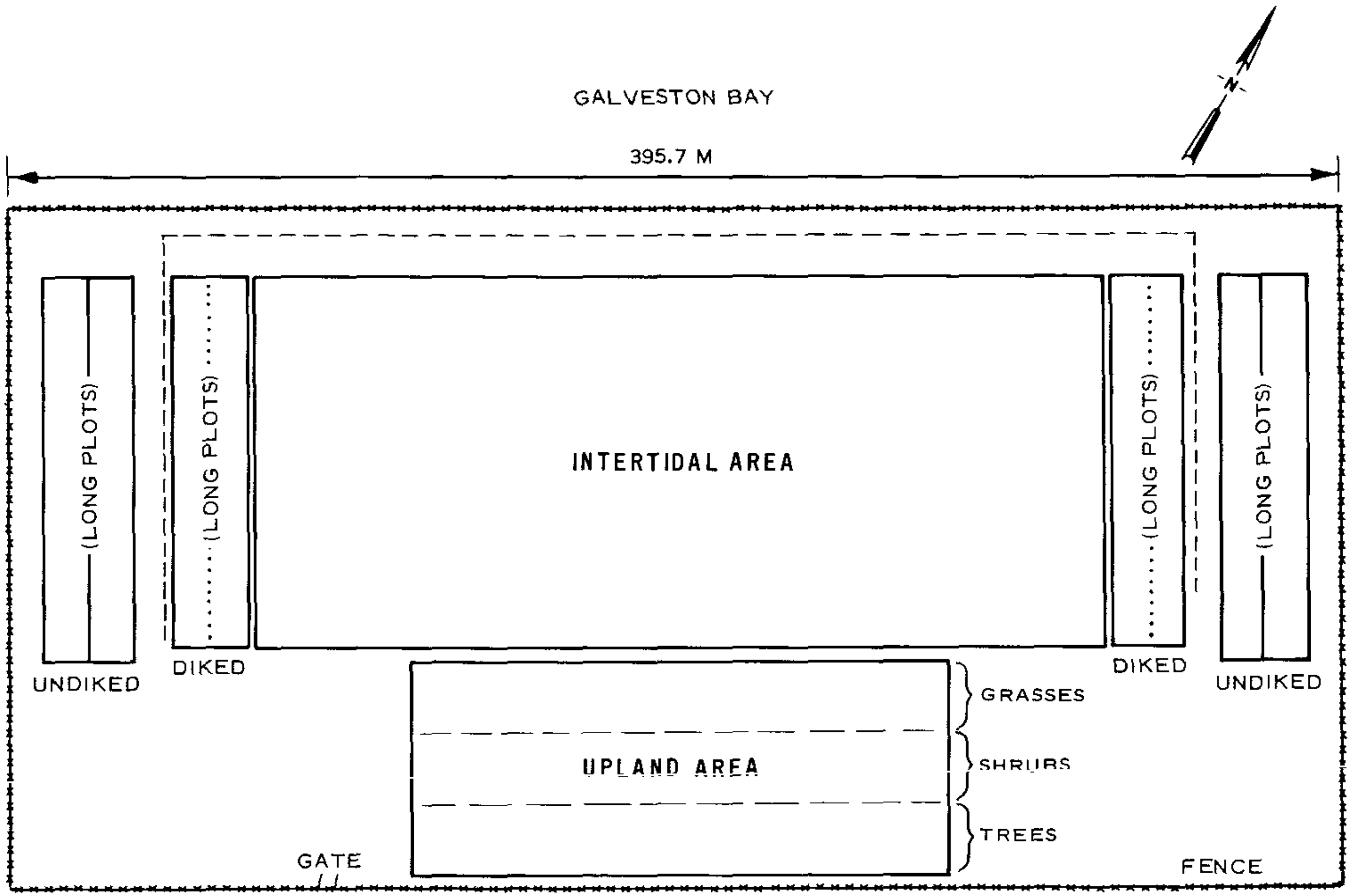


Figure 9. Field layout of the site

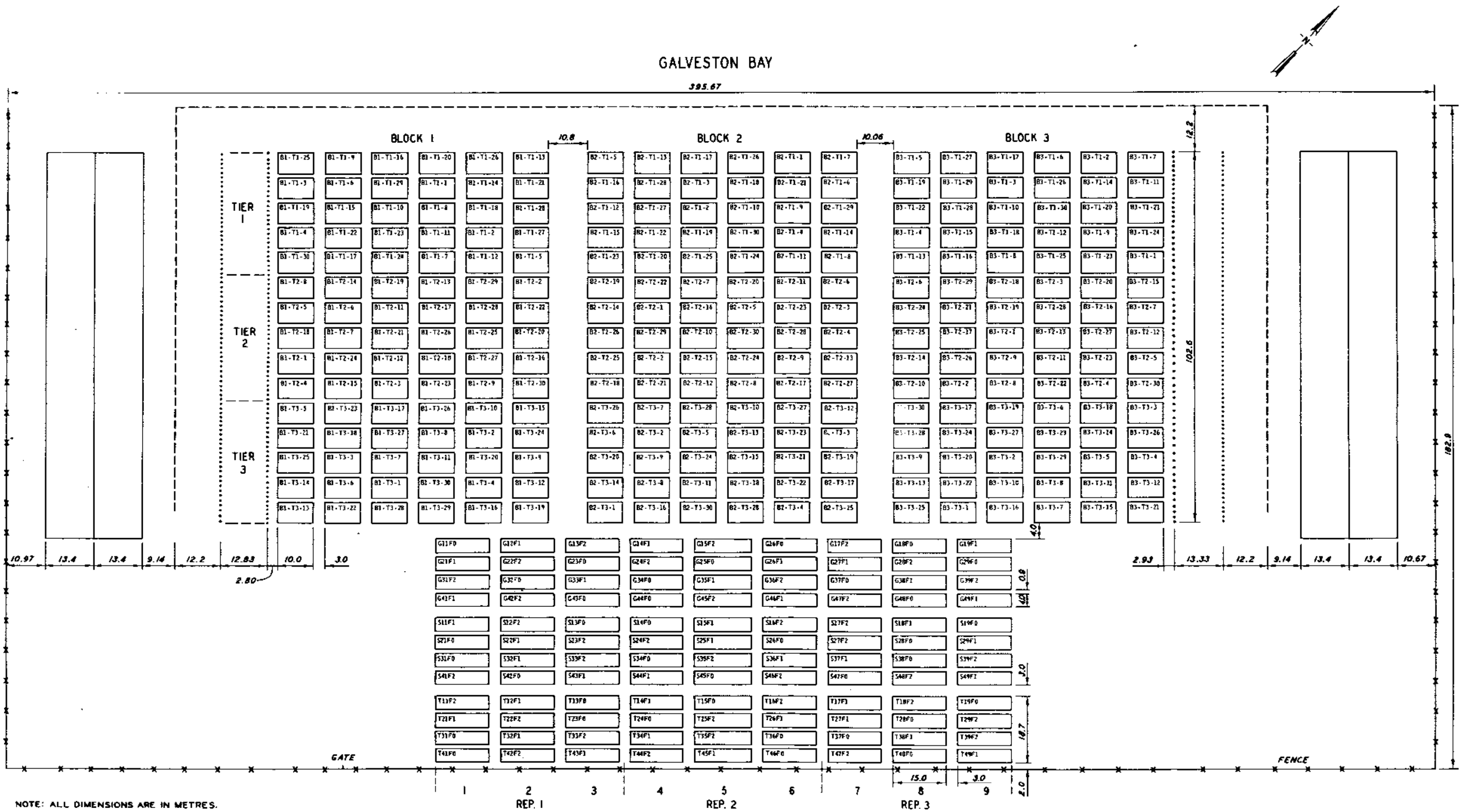


Figure 10. Experimental plot layout

28. <u>Experimental procedure</u>. The sprigged plots of smooth cordgrass and saltmeadow cordgrass were fertilized and planted 22 July through 4 August 1976 for a summer planting, 1-4 February 1977 for a winter planting, and 11-12 and 30-31 May 1977 for a spring planting. The two species were seeded and fertilized 21-23 March 1977. Germination was tested prior to seeding to determine the appropriate storage conditions and seeding rates. Details of seed germination tests, plant procurement, plant handling and planting techniques can be found in Webb et al. (1978). Following planting, the plots were monitored for plant survival, performance, and production from 22 August 1976 to 15 November 1977. Evaluations were made at least once a month except for January, March, and August 1977.

29. The following characteristics were measured by non-destructive sampling: plant height, plant density, number of stems per plant, number of stressed or stable plants, vegetative reproduction, percent foliar cover, and the number of plants with flowers, seed heads, and new growth. Biomass of roots and shoots was destructively sampled during November of each year using a circular core, 25 cm deep and covering a 0.1-m^2 area. Three 1 by 3-m quadrats per plot were used for permanent, non-destructive sampling while destructive plant samples were selected at random from the remainder of the plot. Other details of the methodology can be obtained from Webb et al. (1978).

Soils in the intertidal zone

30. Prior to planting and fertilization in July 1976, the intertidal substrate was sampled to characterize baseline conditions from which to make comparisons after planting and fertilization. Six 30-cm-long cores were taken on 29 June 1976 from the intertidal sites using a 7.6-cm diameter polyvinylchloride (PVC) pipe. Three cores were from areas commonly submerged and three were from portions of the site subjected to intermittent flooding. The cores were sectioned into 0-15 and 16-30-cm segments and analyzed. Shortly after planting on 18 August 1976, nine 105-cm cores were taken from the high fertilizer level, smooth cordgrass plots and handled as described above.

31. In subsequent analyses for site monitoring, a composite sample of ten cores was taken from each of the 270 marsh plots and the 35 intertidal reference plots on 11 November 1976, 27 June 1977, and 14 October 1977. Cores were taken to a depth of 30 cm with a 2.5-cm diameter soil tube. The samples were frozen in dry ice and transported to the laboratory where the entire 30 cm of the ten cores were blended and subjected to chemical analyses. Deep 105-cm cores were taken on 11 November 1976, 27 June 1977, and 14 October 1977, and analyzed by 15-cm segments.

32. All soil samples were analyzed for percent soil moisture, soil pH, total Kjeldahl nitrogen, ammonium nitrogen, nitrite and nitrate nitrogen, and oxalate extractable phosphorus. For all samples other than those taken on 11 November 1976 and 27 June 1977, analyses also included organic matter, particle size, cation exchange capacity, exchangeable bases, salinity, total phosphorus, total sulfide, and lime requirement. Other measurements included precipitation, soil temperature, elevation, and the potential for chemical reduction and oxidation (redox potential). Precipitation was collected and analyzed for concentrations of nitrogen, phosphorus, calcium, potassium, and sodium. Details of methodology may be found in Webb et al. (1978).

Upland Zone

33. Experimental design. The experiment in the upland area was designed to study survival and growth of three vegetational forms: trees, shrubs, and grasses. The trees included sand pine (*Pinus clausa*), live oak (*Quercus virginiana*), and salt cedar (*Tamarix gallica*). Included among shrubs were wax myrtle (*Myrica cerifera*), gulf croton (*Croton punctatus*), and winged sumac (*Rhus copallina*). The grasses were coastal bermuda grass (*Cynodon dactylon* var *alecia*), bitter panic (*Panicum amarum*), and bluestem (*Andropogan perangustatus*). Grasses were planted in rows along the lowest elevations in the upland area, then shrubs at the intermediate elevations, and trees at the highest elevations (Figure 9). Each of the three elevational zones was divided into four rows of plots; each plot was 4 by 15 m on a side, and three rows were planted with the three species of each vegetational form

(Figure 10). The fourth row in each zone was left unplanted. The plots in each row were divided into three sets or replicates of three plots each and each set in the three plots was fertilized differently, including one plot that was not fertilized. See Table 3 for a schedule of the treatments. This design later was modified to test the effects of additional fertilization during the second growing season on half plots of coastal bermuda and bitter panic grasses. Specific details of the experimental design and analysis can be obtained from Webb et al. (1978).

34. Experimental procedure. All upland transplants were collected from local sources with the exception of sand pine and live oak, which were purchased from nurseries in Georgia and Louisiana, respectively. The upland was planted from 29 June to 8 July 1976 and from 19 January to 9 February 1977. The grasses were sampled from three, 1 by 3-m quadrats located in each third of each plot. Because only 16 trees and shrubs were planted per plot, all of them were measured for all characteristics except for destructive estimates of biomass. The non-destructive measurements for grasses included percent survival, plant height, miscellaneous environmental effects, vegetative reproduction, times and amounts of fruiting and seeding, animal damage, percentage of foliar cover, and number of invading species and plants per quadrat. Non-destructive measurements for the trees and shrubs consisted of percent survival, plant height, and number of invading species and plants. Non-destructive measurements were made on 2 September 1976, 9 November 1976, 21-22 June 1977, and 22 September to 5 October 1977. The biomass of plant roots and shoots was sampled destructively by taking three plants from each quadrat at the end of the growing season. Grasses were destructively sampled from 9-19 November 1976, and 22 September to 6 October 1977. Shrubs and trees were sampled for biomass only at the end of the 1977 growing season from 22 September to 6 October. Refer to Webb et al. (1978) for details about plant procurement, handling, fertilization, and measures of plant performance.

Soils in the Upland Zone

35. Three 30-cm cores were taken on 29 June 1976 from the upland site. Sampling techniques, handling, and analyses were the same as those described for the initial sampling of the intertidal zone. No further substrate sampling was conducted in the upland.

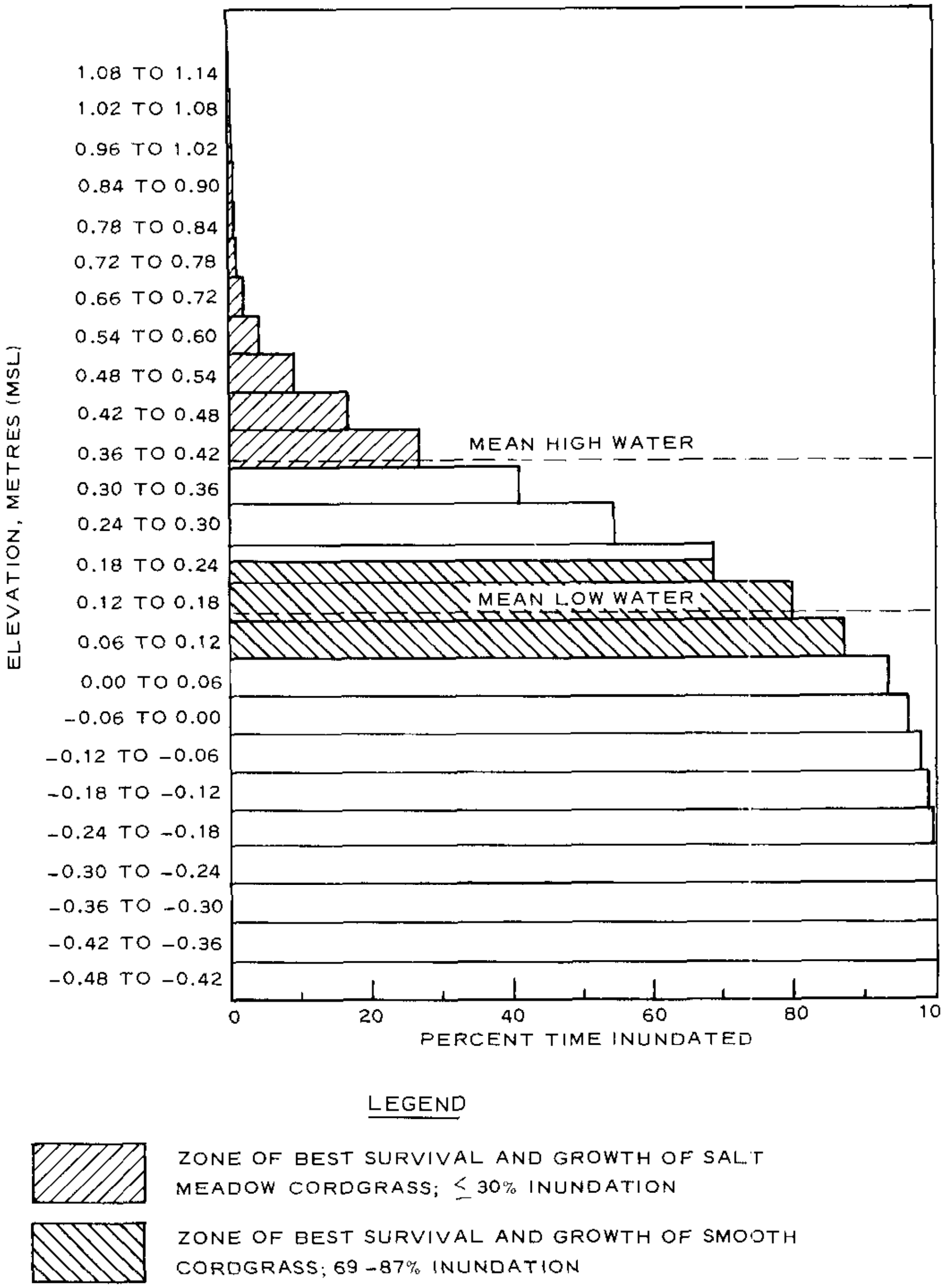
Results and Discussion

Intertidal Zone

36. Elevation. Elevation determined the percentage of time that the plants were inundated and was a key factor determining planting success, subsequent plant performance, and the distribution of soil characteristics. Tide levels were strongly influenced by wind direction and velocity and were highly variable (for example, tides covered an elevation near mean high tide half of the time for a 34-day period in spring 1977). This introduces a confounding variable into the interpretation of the elevational and seasonal factors influencing plant success. However, observations at this site confirm observations at other habitat development sites regarding the relative elevations at which smooth cordgrass and saltmeadow cordgrass survive and grow (Kruczynski et al. 1978, Cole 1978). That is, smooth cordgrass grew most successfully in the lower tidal range whereas saltmeadow cordgrass was most successful in the upper third of the tidal range.

37. Smooth cordgrass survived and grew best at lower elevations, 0.06 to 0.21 m above mean sea level, where tidal inundation occurred 69 to 87 percent of the time from 1 February to 31 August 1977 (Figure 11). However, sprigs of this species were partially successful at all elevations of the intertidal area, except at approximate mean high water which will be discussed below. Saltmeadow cordgrass performed best in the upper intertidal zone at an elevation above 0.37 m msl. Few plants of this species survived where the substrate was inundated more than 25 to 30 percent of the time (Figure 11).

38. Tidal ranges were variable from one season to another because of the controlling influences of winds. During the period of

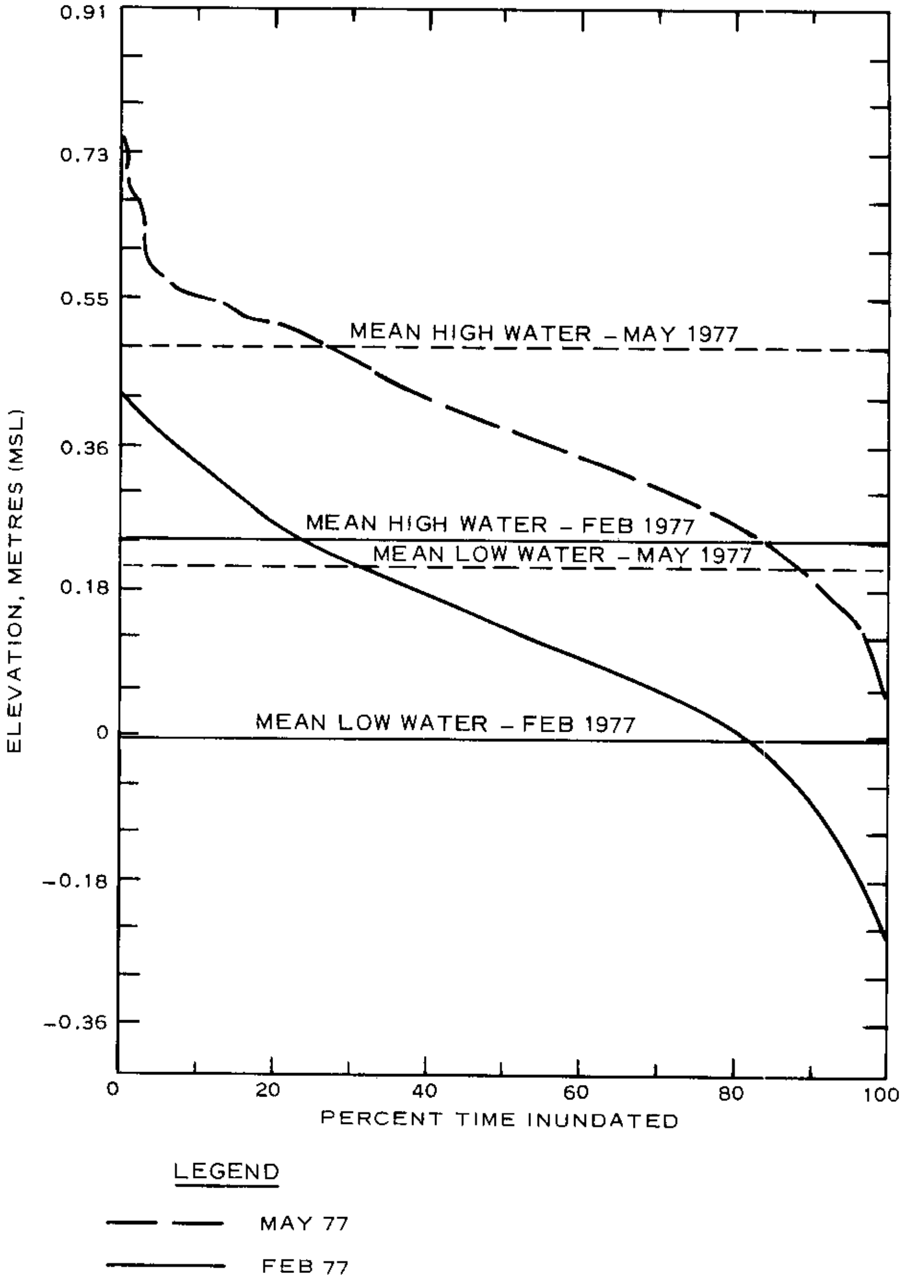


NOTE: TIDE DATA ARE FROM 1 FEBRUARY TO 31 AUGUST 1977, A PERIOD COVERING THE MAJORITY OF THE GROWING SEASON.

Figure 11. Elevational zones of best survival and growth of saltmeadow and smooth cordgrass with percent inundation

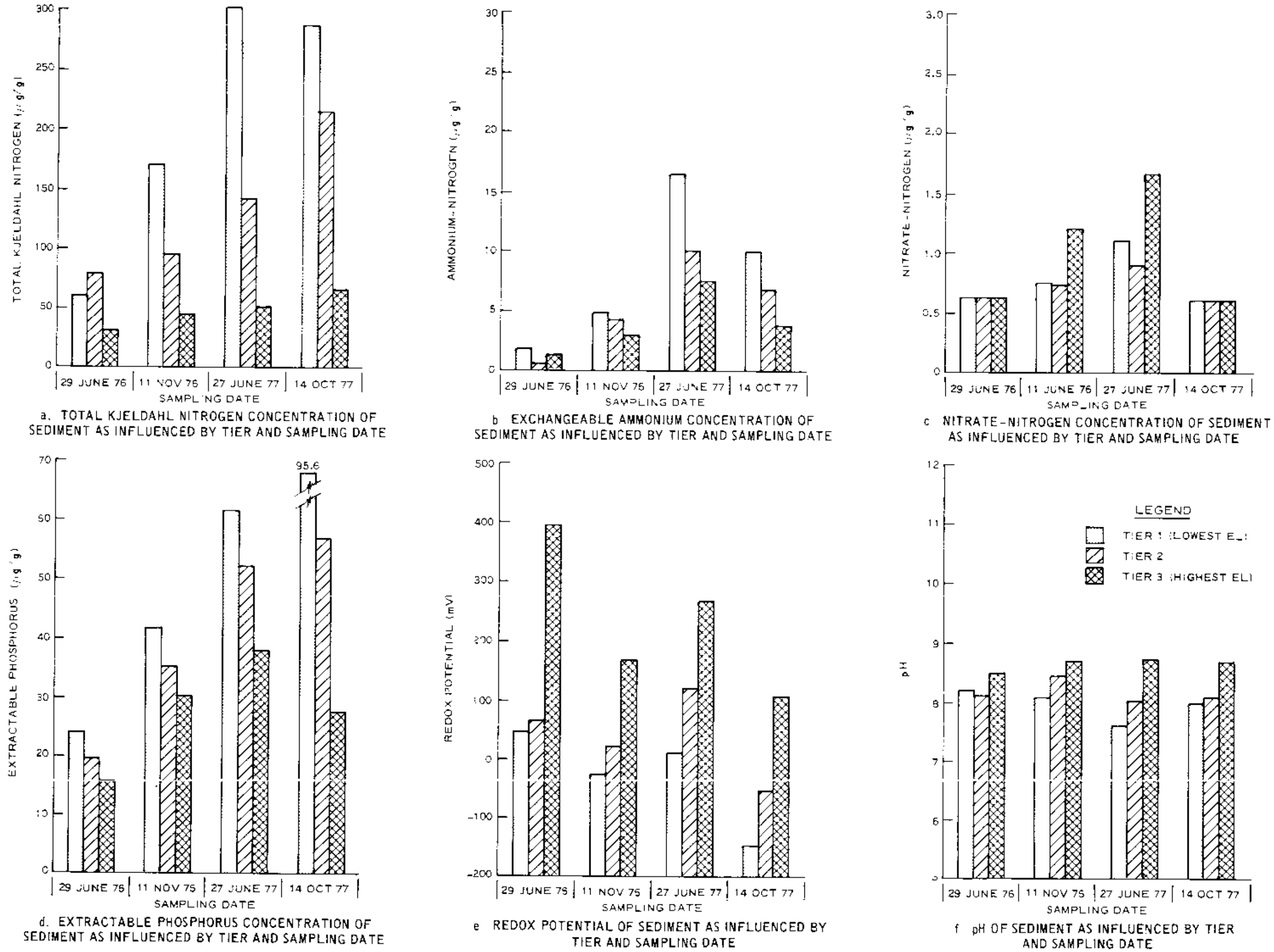
tidal monitoring, February was the month of lowest tides whereas May was the month of highest tides (Figure 12). These differences in tides and levels of inundation affected the elevation at which plants could survive and grow. This was particularly true of the sprigged plants of smooth cordgrass planted in both February and May 1977. Comparisons of the February and May planting indicated that the higher tides in May to June allowed better survival and growth at higher elevations than previously observed in the earlier plantings. These results show how important tide levels and elevation can be to the time and location of marsh grass plantings. This is corroborated by Adams (1963), who studied the effects of elevation on salt marsh plant species in North Carolina and concluded that tide level elevational influences were the primary factors controlling the distribution of salt marsh species.

39. Elevation and time also influenced the substrate characteristics of the intertidal zone and in turn may have affected plant performance. The effects of elevation were apparent in the substrate before the planting experiments began. The gross trends in soil characteristics, given in Figures 13a-f, generally reflect elevation gradients associated with the percentage of time the substrate was inundated. The total Kjeldahl nitrogen, exchangeable ammonium, extractable phosphorus, cation exchange capacity, organic matter, and percentage silt and clay were generally low, as expected for sandy substrate, and all decreased with increasing elevation. These results follow the same trends as reported by Fedler (1977) for organic matter. The nitrate nitrogen and redox potential increased with increasing elevation in direct relationship with the aeration of the substrate (Figures 13c and e). As expected in substrates inundated with seawater, the pH averaged above 8.0 (Figure 13f) and exchangeable calcium and sodium were the most concentrated exchangeable bases. After planting and fertilization, the same elevational trends remained but concentrations of organic matter, nitrogen and phosphorus generally increased over time. The presence or absence of plants appeared to have no appreciable effect on the levels of total Kjeldahl nitrogen or extractable phosphorus in the substrate as can be seen in Figures 14a and b.



NOTE: SPRIGGINGS OF SMOOTH CORDGRASS OCCURRED IN FEBRUARY AND MAY 1977.

Figure 12. Maximum (May) and minimum (February) tidal ranges for an 8-month monitoring period (January-August 1977)



a. TOTAL KJELDAHL NITROGEN CONCENTRATION OF SEDIMENT AS INFLUENCED BY TIER AND SAMPLING DATE

b. EXCHANGEABLE AMMONIUM CONCENTRATION OF SEDIMENT AS INFLUENCED BY TIER AND SAMPLING DATE

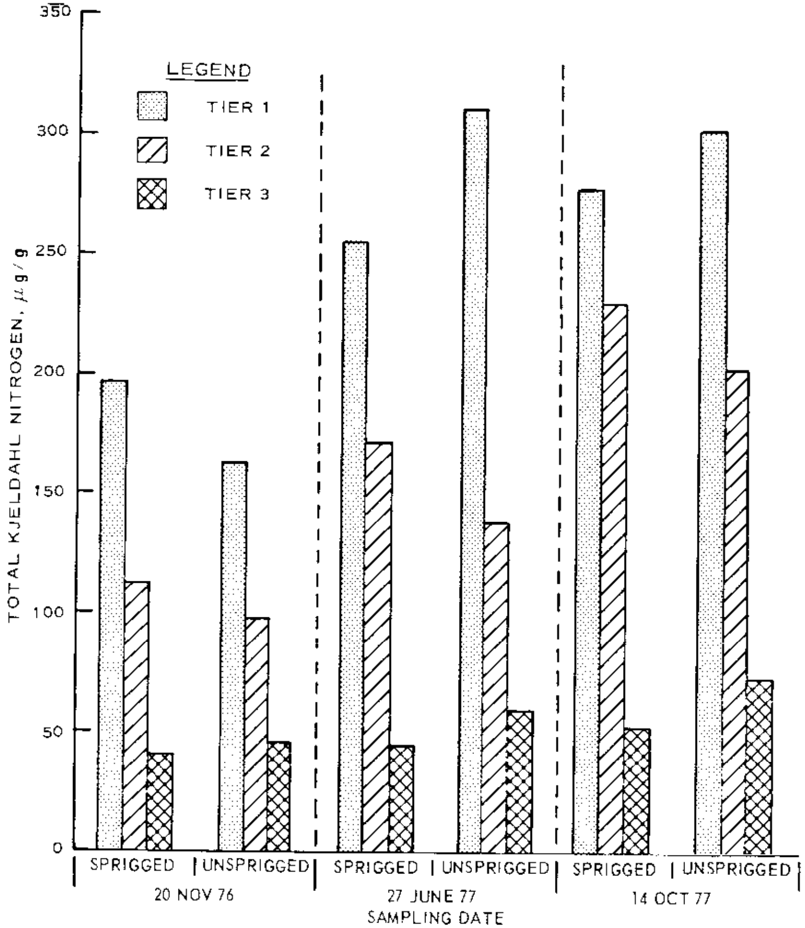
c. NITRATE-NITROGEN CONCENTRATION OF SEDIMENT AS INFLUENCED BY TIER AND SAMPLING DATE

d. EXTRACTABLE PHOSPHORUS CONCENTRATION OF SEDIMENT AS INFLUENCED BY TIER AND SAMPLING DATE

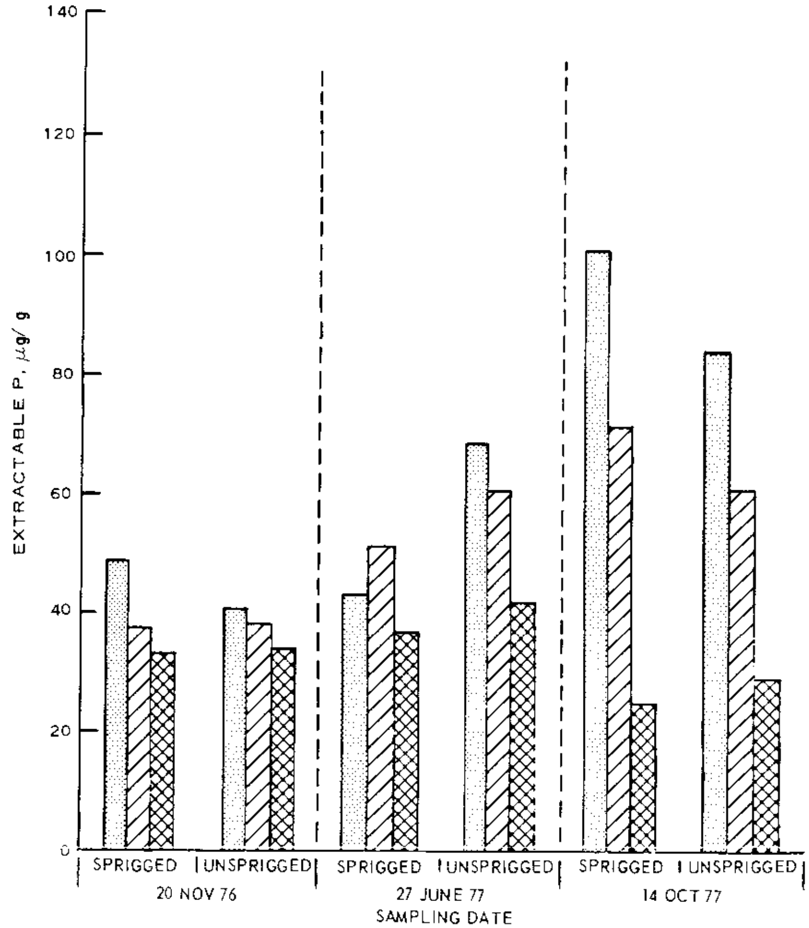
e. REDOX POTENTIAL OF SEDIMENT AS INFLUENCED BY TIER AND SAMPLING DATE

f. pH OF SEDIMENT AS INFLUENCED BY TIER AND SAMPLING DATE

Figure 13. Comparisons of nutrient concentrations wih elevation (tier) and time



a. TOTAL KJELDAHL NITROGEN OF SEDIMENT AS INFLUENCED BY TIER, SAMPLING DATE AND PRESENCE OF SPRIGGED SMOOTH CORDGRASS



b. EXTRACTABLE PHOSPHORUS OF SEDIMENT AS INFUENCED BY TIER, SAMPLING DATE AND PRESENCE OF SPRIGGED SMOOTH CORDGRASS

Figure 14. Comparisons of nutrient concentrations with elevation (tier) and and time and among planted and unplanted plots

40. The major factor contributing to changes in soil characteristics of the intertidal zone was the rate of sedimentation. The sandbag dike lowered hydraulic energies at the experimental site which in turn led to greater accumulations of fine-grained sediments, particularly silts and clays rich in organic matter. The increased depth of new sediment ranged up to 15 cm. Coarse sandy material was deposited between the dike and the plots. The greatest depths of clay and silts accumulated in the lowest elevations of the intertidal experimental area and decreased with increasing elevation. These fine-grained sediments contained more organic matter and available nutrients than underlying sands. Therefore, one would expect organic nitrogen, ammonium, and phosphorus levels to increase with time and decrease with increasing elevation.

41. The rapid rate of sedimentation caused by the dike also accounts for the similarity of the substrates found in planted and unplanted plots (Figures 14a and b). Importation of nutrients associated with the new sediments far outweighed any influence of planting that may have existed. In another situation in North Carolina, Cammen (1976) found that fine-grained sediments accumulated in artificially planted areas more than in non-planted areas. He believed that the plants lowered turbulence enough to precipitate suspended solids. This may have happened at the Bolivar site; however, effects of the dike were great enough to hide any plant effects that may have existed.

42. The relationship of nutrient concentration and elevation tended to be reflected in the distribution of the plants. Figure 15 shows that both smooth cordgrass and saltmeadow cordgrass tended to produce more biomass at the lowest elevations within the range of elevations each could tolerate. This may indicate a response to the greater availability of nutrients at lower elevations.

43. An incongruous zone of poor survival and growth for plants became evident near mean high water, 0.37 to 0.52 m above mean sea level. Recent investigation by Hossner* suggests that this zone was

*Personal communication, Hossner Lloyd R., December, 1977. Soils Chemist, Soil and Crop Sciences Dept., Texas A&M University, College Station, Texas.

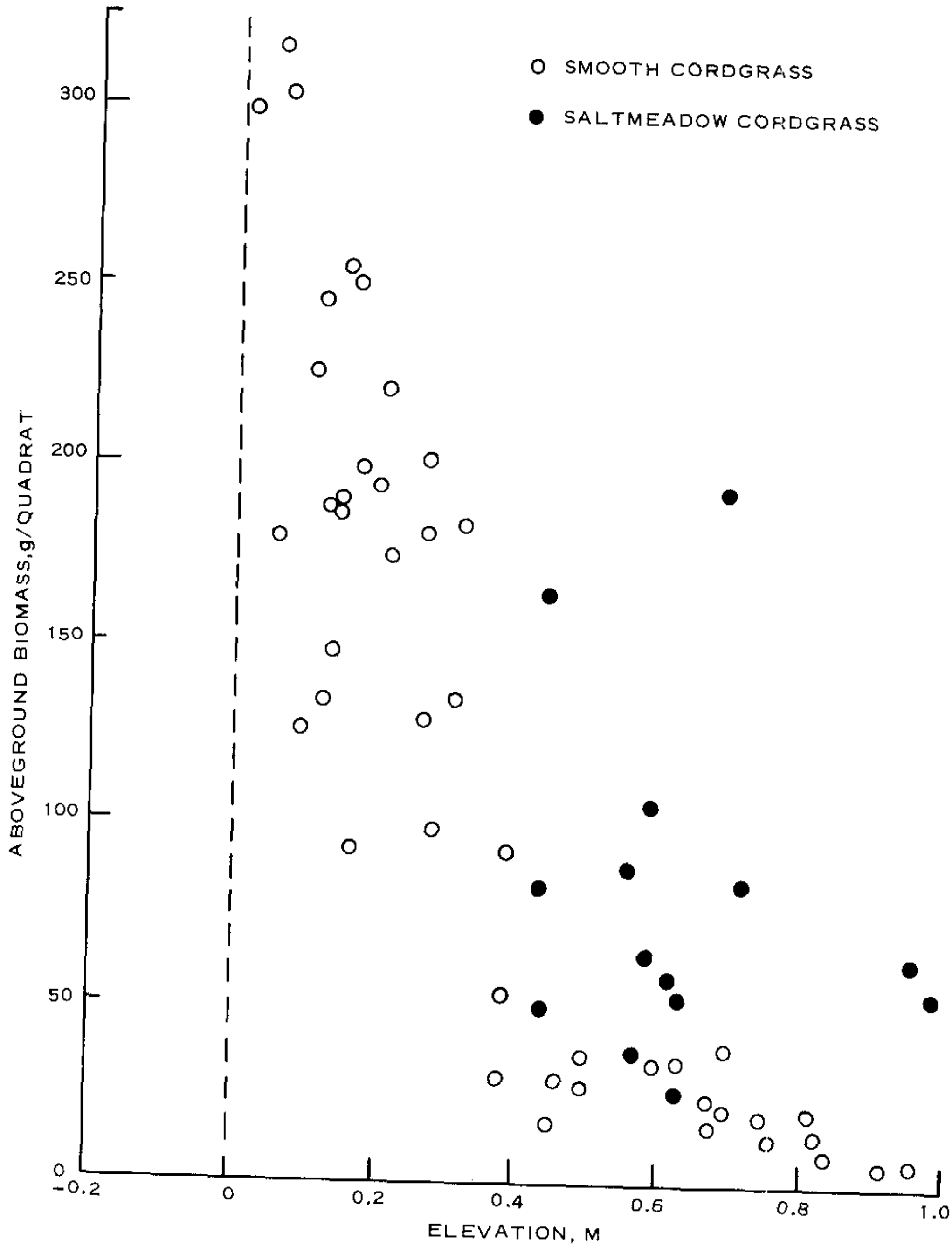


Figure 15. Relationship of plant productivity to elevation

caused by an accumulation of salt in the soil when the substrate remained above high tide for long periods and the evaporative concentration of salts exceeded leaching by rains. This observation at Bolivar Peninsula is similar to cases of salt toxicity reported by investigators on the west coast (Mahall and Park 1976) and the east coast (Kurz and Wagner 1957, Adams 1963, Stalter and Batson 1969, and Stalter 1973).

44. Evaluation of cultural practices or treatments. Sprigging was shown to be a much more reliable planting practice at Bolivar Peninsula than seeding. Either smooth cordgrass or saltmeadow cordgrass may be seeded rather than transplanted at sites like Bolivar, but the risk of failure is high due to tidal washout. If seeding is attempted, it should be done in the upper tidal zone or if lower zones are seeded, at a time when tidal flushing is infrequent, such as in late winter or early spring. Observations during the study indicated that seeds were washed from the substrate by waves and seedling emergence of smooth cordgrass and saltmeadow cordgrass was limited to the upper third of the intertidal zone. This was in a zone where inundation was rare but where soil moisture was high enough for initial establishment. There was no observed seedling emergence in plots below 0.43 m msl. Dry conditions at the highest elevations also prevented seedling establishment. Broome (1972) reports similar evidence in seeding dredged material in North Carolina. He states that in lower zones, there is a problem in keeping the seed in place until they germinate since they are easily dislodged and washed away by wave action. In contrast, sprigging proved successful at Bolivar at almost all elevations according to the species zonation discussed above. In future habitat development operations at sites like Bolivar, sprigging is recommended but it should be noted that seeding is inexpensive and can be used to augment sprigging, especially at higher elevations and during times of infrequent tides.

45. Fertilization did not clearly effect differences in marsh plant survival, vegetative reproduction, growth in height, or seed production of either plant species tested in intertidal experiments. The rapid rate of sedimentation and nutrient influx may have over-

shadowed any possible effects of fertilization. Therefore, initial fertilization did not seem worthwhile in the intertidal zone at the Bolivar site.

46. The sandbag dike was an effective wave stabilizer. Plantings in plots outside the diked area had lower survival and were in poorer condition throughout the study period than plantings within the diked area. Figure 16 illustrates the differences in response of plants within the dike versus those outside the dike. Plants within the dike are more dense and are darker in appearance indicating healthier stands of plants than those outside the dike. It is difficult to conclude that this difference was caused solely by the wave reducing effort of the dike, although this certainly would seem to be an important factor. It is also possible that the sedimentation and nutrient influx caused by the dike in the experimental area were the major reasons for the difference in plant performance. In either case, it seems unlikely to expect much success with marsh establishment in areas with excessively high wave energies unless energy is dissipated.

47. Successful sprigging attempts were achieved with both marsh species in both late winter and summer. However, late winter or early spring planting is recommended in the Texas gulf coast area for maximum recovery from planting shock and to insure maximum plant densities and growth by the end of the growing season.

48. Plant invasion. Plant invasion of the intertidal area by non-planted species was not a problem. The invasion that did occur was primarily by smooth cordgrass and saltmeadow cordgrass in the highest tier. The only invading plants observed in the lower two tiers were smooth cordgrass seedlings and tillers from already established plots. Minor invasion at the highest elevations did occur by the species mentioned below and which are listed in the order of number invading (greatest to least): seashore dropseed (*Sporobolus virginicus*), American bulrush (*Scirpus americanus*), fimbry (*Fimbristylis castaneum*), yellow nutgrass (*Cyperus esculentus*), salicornia (*Salicornia* spp.), and coastal bermuda. At elevations above mean high tide, invading species may include only local plants adapted to the marshland environment.

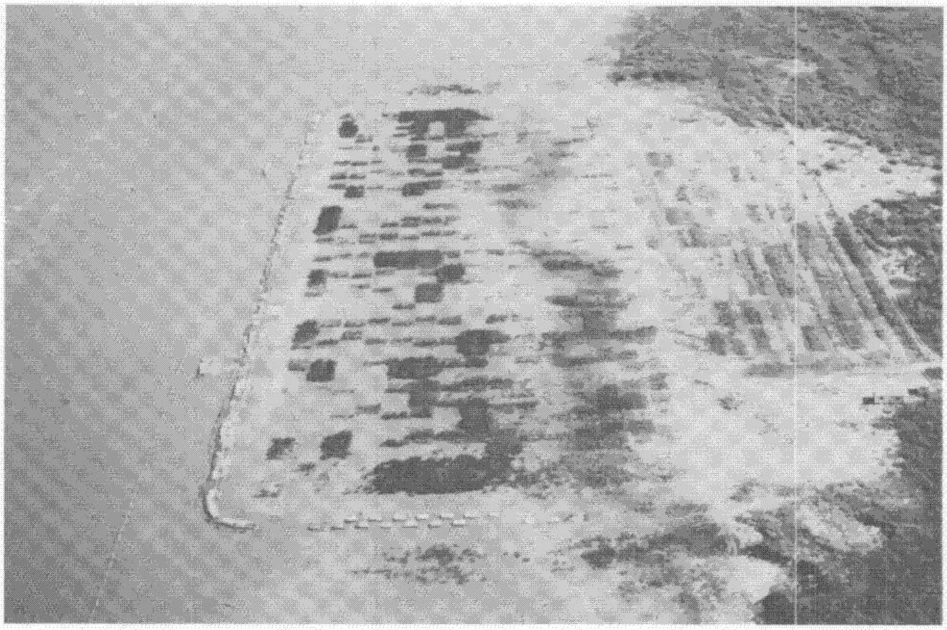


Figure 16. Plant response due to apparent lack of protection from waves by the dike. Note the denser and healthier plants inside the dike versus those outside

Upland Zone

49. Elevation. Variation in elevation, although not great, appeared to be related to the success or failure of most species planted in the upland. West side plots were about 0.15 m lower than east side plots and were low enough to be exposed to tides and frequently flooded or wet soils. Plants that performed poorly in low, wet soils included coastal bermuda grass, bitter panic grass and gulf croton. In contrast, salt cedar and sand pine performed poorly on the higher dry soils. The most tolerant of variation in elevation and moisture were live oak, winged sumac and wax myrtle. The bluestem transplants performed poorly over the entire site even though they grew naturally in the surrounding area. Transplanting might be a poor method of propagating bluestem whereas seeding might be better, but this needs further experimentation. The percentages of plants surviving during a 9- to 15-month period were:

Species	Average Survival, %
bluestem grass*	5.4
coastal bermuda grass*	81.3
bitter panic grass*	84.7
salt cedar**	28.4
sand pine**	31.9
live oak**	96.5
winged sumac**	66.0
gulf croton**	22.2
wax myrtle**	62.9

*Evaluated on 22 June 1977

**Evaluated on 26 September 1977

50. Fertilization. Coastal bermuda and bitter panic grasses grew better when fertilized but fertilization had no effect on their survival. Plant growth, density, and other performance factors for both grasses greatly increased with repeated applications of fertilizer.

51. The survival of wax myrtle and the growth in height of sand pine were increased by fertilization, but no other fertilizer effects were observed among the other trees and shrubs. The influence of elevational variation may have overshadowed the effects of fertilization on other species. As Webb et al. (1978) noted, the effects of fertilization on plant performance may not be noticeable in trees and shrubs for several years; therefore, the long-term fertilizer effects in this situation are unknown. Tentatively, the planting success of most species was not diminished and for some species it may be improved by fertilizing upland, sandy, dredged material.

52. Plant invasion. Greatest invasion occurred at intermediate elevations in the upland by such species as yellow nut grass, American bulrush, western ragweed (*Ambrosia psilostachya*), Drummond sesbania, seashore dropseed, and saltmeadow cordgrass. Extremely wet or dry conditions of plots appeared to inhibit invasion. Invasion was more noticeable in fertilized than unfertilized plots. Invaders were more prevalent in plots of trees and shrubs that were less dense and had less ground cover. In fact, all but the unplanted plots in the trees and shrubs were weeded to eliminate competition by Drummond sesbania since the objective was to evaluate the survival of plants and their response to fertilization without outside variables. However, the evaluation of invaders was facilitated by the monitoring of unplanted plots. The plots planted to coastal bermuda and bitter panicum did not receive much invasion, probably because invaders could not get started in the dense ground cover of the two grasses.

53. Weeding was essential for this study, at least in the plots planted to trees and shrubs. For future habitat development the decision to weed or not to weed must be made in light of the value of target plant species wished to be developed versus the value of the invading plants. On this site, the target plant species were considered to have more experimental and wildlife value than the invading plants. If the invading plants had been allowed to grow unchecked, they probably would have jeopardized the survival of the plants being developed.

Summary and Conclusions

54. This study indicates that smooth cordgrass and saltmeadow cordgrass can be artificially established in an intertidal zone on dredged material, but particular attention needs to be given to elevational variation. Elevational gradients within the intertidal zone determine the amount and periodicity of inundation which, in turn, affect the sedimentation rate and availability of nutrients associated with the new sediments, the accumulation of salts in the substrate, and the germination and survival of seeds. Although smooth cordgrass can be transplanted successfully at Bolivar Peninsula over most of the intertidal zone, it grows best below mean high water. In contrast, saltmeadow cordgrass survives and grows best in periodically inundated areas above mean high water. Either species may be seeded rather than transplanted but the risk of failure is high because of seed washout by tidal waters. Fertilization does not appear to significantly affect growth in the intertidal zone.

55. Planting upland areas with grasses, shrubs, and trees was partially successful, depending on the species and the variation of soil moisture in the experimental area. Species that generally performed best were coastal bermuda grass, bitter panic grass, live oak, winged sumac and wax myrtle. Sand pine, gulf croton and salt cedar might be suitable in areas where their soil-moisture requirements are likely to be more uniformly met. Plant invasion was a problem in the plots planted to trees and shrubs. Except for the unplanted plots in the tree and shrub areas, invaders were removed. For future habitat development efforts in this area, it is recommended that weeding be done until the planted species are established.

PART V: AQUATIC BIOLOGY

Methods and Materials

56. Studies in aquatic biology were undertaken to assess the environmental impacts that habitat development would have on fish and benthic invertebrates. The effects of habitat development were assessed through interpretation of patterns in the composition, feeding habits, and resource value of the aquatic animals in the vicinity of the experimental area. A baseline survey was conducted from March to October 1975 to provide an inventory and assessment of fish and benthos prior to site construction. After construction of the site a second study was conducted from July 1976 to June 1977, to document changes associated with the habitat development.*

57. For the baseline study, fish and crabs were collected only during the day in intertidal areas using a 15-m bar seine with a 13-mm stretch mesh and a 1.8-m beam trawl with a 1.3-m wide body of 0.47-mm mesh. Subtidal areas were sampled with a 3-m wide, flat, shrimp trawl of 25-mm stretch mesh. A 0.025-m^2 Eckman grab was used to take macrobenthic invertebrate samples, which were washed through a 500-μm sieve. Macrobenthos were functionally defined as the invertebrates retained on the 500-μm sieve. Samples were taken in both intertidal and subtidal areas within and on either side of the location initially proposed for habitat development (Figure 17).

58. After the new habitat was constructed and planted, fish samples were taken day and night inside and outside of the diked area with the following sampling devices: 7.62-m beach seine of 6.35-mm mesh; 1.5-m wide push net with 4.7-mm mesh; 0.9-m diameter hoop net having 25.4-mm bar mesh; and standard minnow traps. Also during this period, feeding habits were determined for selected fish species. Processing and analysis of fish stomachs followed methods described by

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* As noted earlier in the Introduction of this report, the site was moved 305 m to the east after most baseline samples were made.

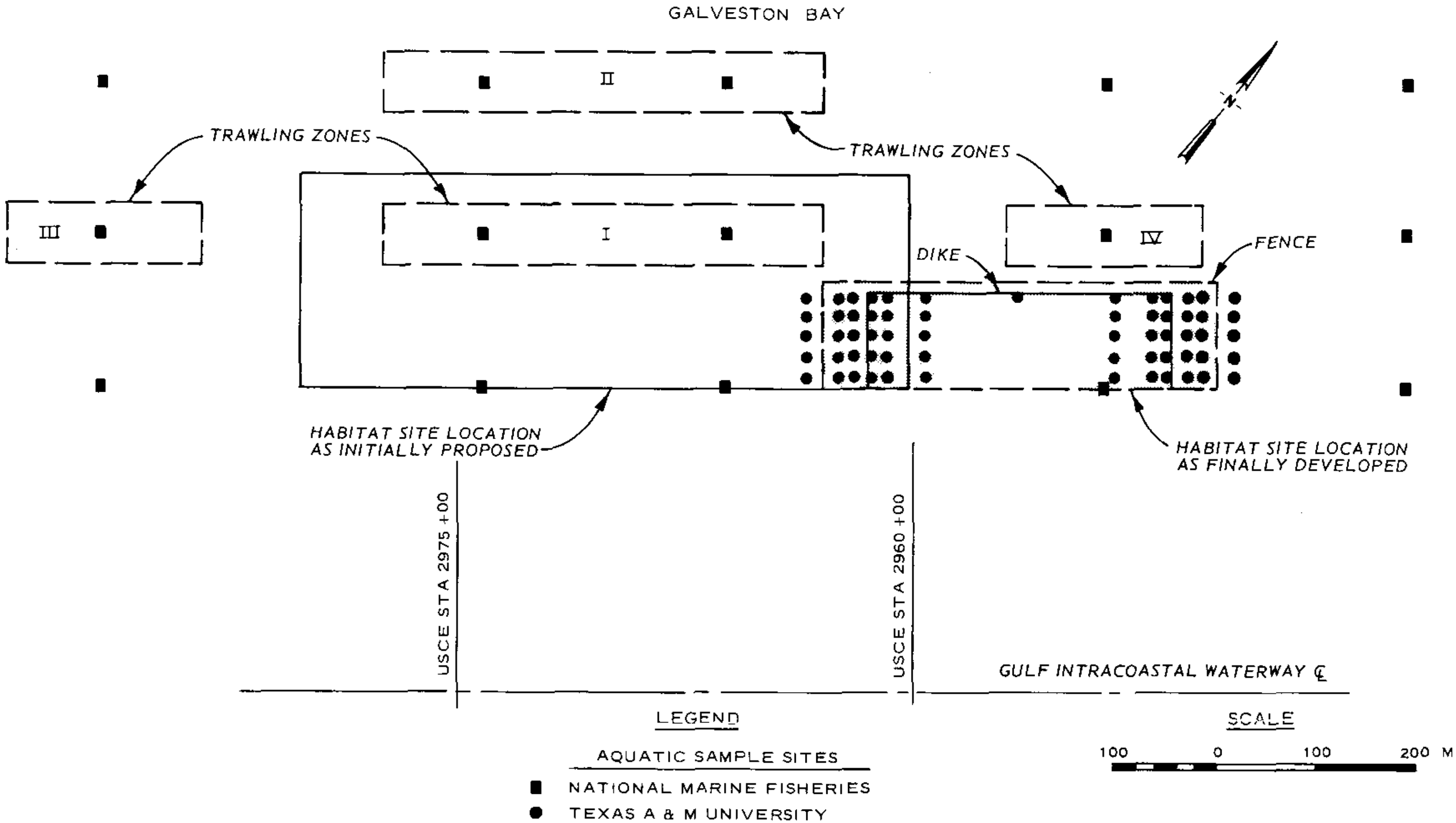

Figure 17. Locations of preconstruction samples collected by the National Marine Fisheries Service and postconstruction samples collected by Texas A&M University

Borgeson (1966). Crabs were caught with baited, commercial pots. For most of this study the benthos was sampled by hand-digging a single 0.05-m^2 area 20 cm deep at each sampling station. During the last three months two samples were collected from each station with a 0.008-m^2 core and then combined to make the total area sampled 0.016-m^2. The samples also were washed through a 500-μm sieve. Benthic samples were taken at 5 elevations in 6 different habitat situations (Figure 18) within the experimental area. For further details of methods see Lyon and Baxter (1978) for the baseline study and Webb et al. (1978) for the post-propagation study. Supplemental analysis of the benthic data can be found in Diaz (1978).

Results and Discussion

59. Prior to site construction, 47 species of fish were found in the area; the three most abundant species were Atlantic croaker (*Micropogon undulatus*), gulf menhaden (*Brevoortia patronus*), and white mullet (*Mugil curema*). The abundance of fish was generally low but reflected expected seasonal distribution (Figure 19). The area provided very little to attract or maintain a resident fish community and most of the species caught were transients.

60. The composition of the fish community remained similar after site development, with bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), white mullet, and Atlantic croaker being numerically dominant. The gulf menhaden was twelfth in abundance. The great similarity between baseline and post-construction conditions was expected, since nearly all of the post-construction conditions occurred before vegetation became well developed; consequently, much of the field sampling reflected conditions (unvegetated sandy beach) before the marsh was established. The principal difference in habitat conditions immediately after site construction was the presence of the protective sandbag dike.

61. Distribution of fish and crabs was variable after dike construction. Greatest numbers occurred in bare unprotected areas at

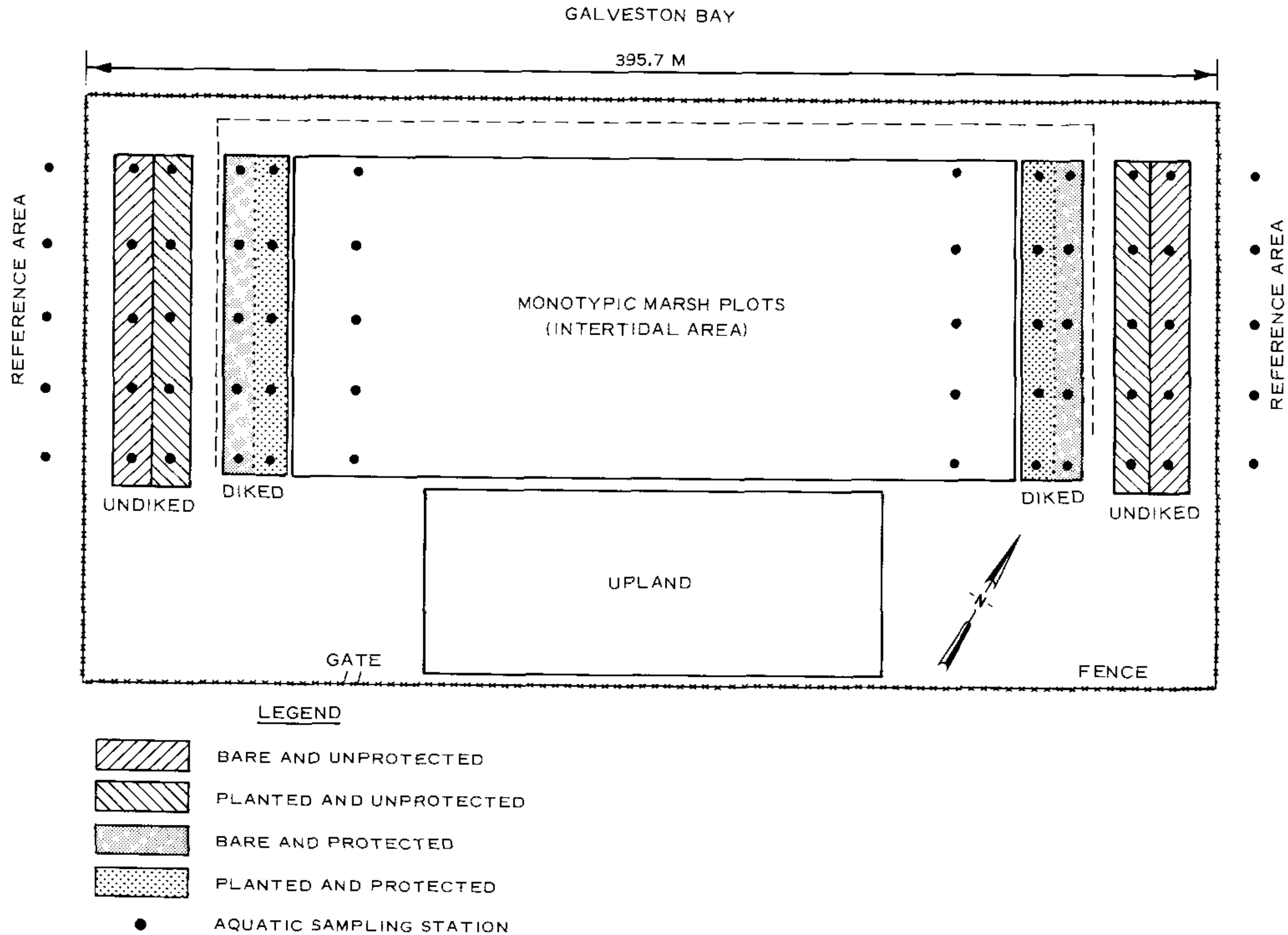

Figure 18. Habitat types and locations of aquatic samples collected after site construction

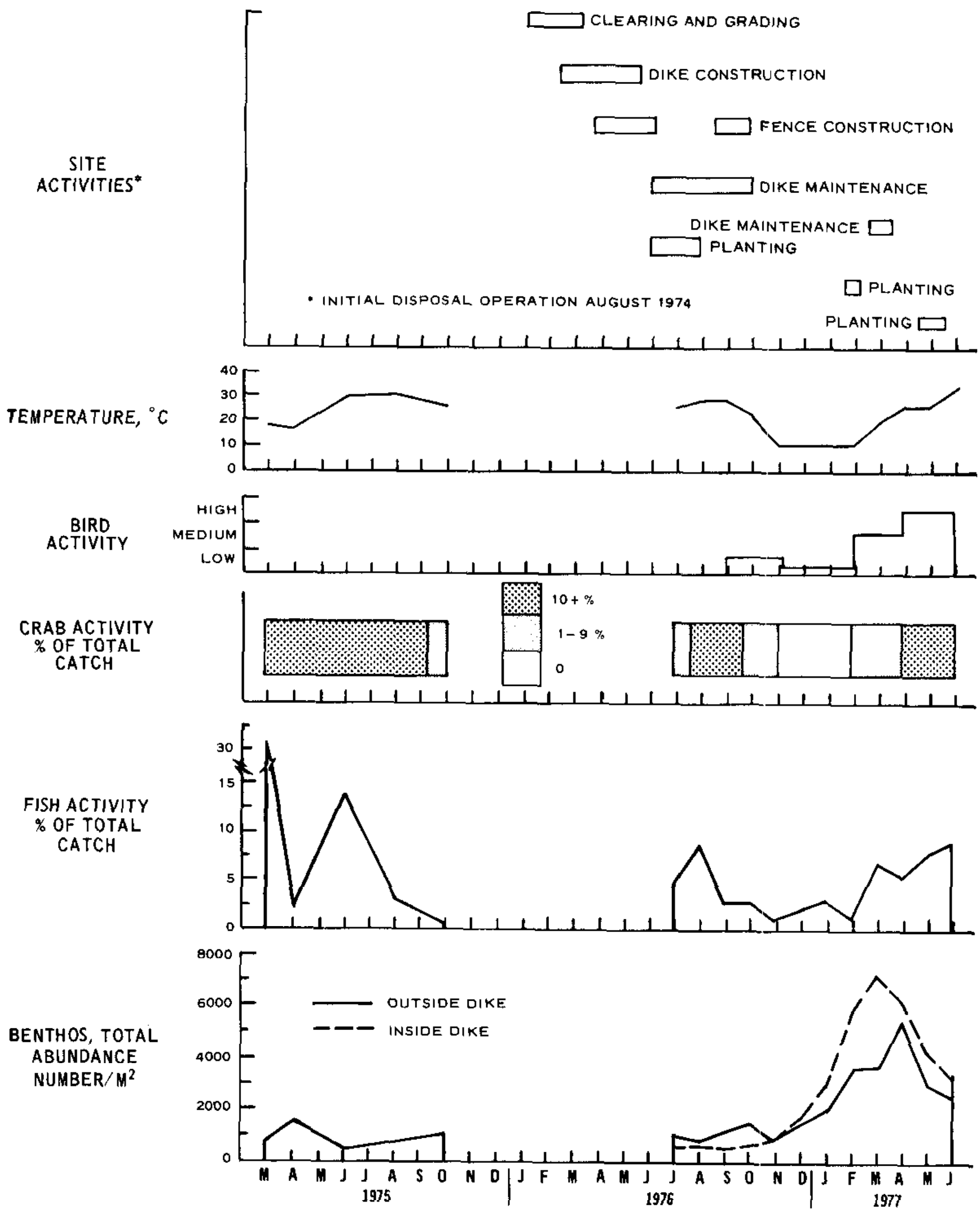

Figure 19. Seasonal distributions of benthos, fish, crab activity, and bird activity in relation to site activities and temperature

night. Catch in bare protected areas was similar to bare areas outside the fence which are identified as reference areas in Figure 18. Sampling within the planted marsh yielded very few individuals. These low numbers may be more a reflection of the sampling gear's inability to catch fish in vegetated areas than of the scarcity of fish since many fish were frequently observed in the planted areas. Species diversity of fish was highest in the reference and bare unprotected areas and lowest within the dike. However, the establishment of the dike seemed to break the otherwise homogeneous environment and attract fish to its more accessible outer edge.

62. The fish studies did not firmly indicate that new habitat was used more than the existing bare area, but as the marsh develops further, the use by fish is expected to increase. A comparison of the fish catch in July 1976 before plant establishment, and June 1977 indicates a slight increase in abundance (Figure 19).

63. The benthic invertebrates that colonized the dredged material were well adapted to the rigorous environment at the site, which is characterized by exposure to waves, high summer temperatures, and strong wind-tides. By March 1975, seven months after the disposal operation, the site had been invaded by the major groups of animals normally associated with sandy substrates in the area. The dominant ones consisted of polychaete worms, an anthurid isopod, and haustorid amphipods. The changes in the abundance of zooplankton, which also provide food for juvenile fish, were generally similar to changes in benthic abundance. The abundance of benthos increased through spring and early summer but declined sharply during midsummer. These changes in relative abundance most likely were caused by a combination of warming temperatures and increased predation by fish and crabs. Water temperatures in July reached 30 deg C in the shallow water that covered the site. Two of the most abundant fish caught at the site, Atlantic croaker and spot, depend greatly on benthos as a primary food source, as does the blue crab (<u>Callinectes sapidus</u>). As the abundance of fish and crab and the temperature declined in the late summer and fall, the benthos began to become more numerous (Figure 19).

64. It is difficult to assess the acute impacts of construction and site preparation on the benthos. There was a slight increase in benthic abundance between the summers of 1975 and 1976. However, this increase probably reflected the additional year the benthos had to populate the original dredged material rather than the effect of construction. The benthos were more abundant outside the sandbag dike than inside the dike from July to October 1976. Within the dike, abundance was most reduced in the planted areas where the most intense site modifications occurred during site preparation. By November, four months after the start of construction, benthic abundance was similar inside and outside the diked area. Despite the similarity in abundance values, the species composition of the benthic communities within and outside the diked area remained different. Inside the diked area, there was a reduction in the species most sensitive to disburbances, such as the anthurid isopod, while less sensitive species, mainly polychaete worms, maintained or increased their abundance.

65. The protected area behind the dike accumulated fine sediment with time. One year after the dike was built there was a thin layer of fine sediment on top of the well-sorted, sandy dredged material. The average thickness of this layer varied from less than 1 cm at the high intertidal areas to 15 cm in low tidal areas along the western side of the habitat.

66. The benthos responded to the changing sedimentary environment with a general increase in species that associate with fine sediments, mainly polychaete and oligochaete worms. Also, as the plants developed, the numbers of shore insects, mainly dipterans and beetles, increased greatly in the study area. Insects were very abundant by the spring of 1977, especially in the planted parts of the higher intertidal zone. The plants also increased habitat diversity for the benthos and shaded the sediment surface from extreme summer heat. The abundance of benthos in the spring and summer following dike construction and planting was 1.5 times greater inside the diked area than in the surrounding vicinity, and within the dike the benthos in planted areas was 1.5 times as abundant as the benthos in bare areas.

67. Fish, crabs, and birds, the main predators on the benthos, used the area heavily in spring and summer and benthic abundance declined from a late-winter high as the abundance of predators peaked. The greatest decline occurred in areas that seemed most accessible to predators, mostly the bare areas within the dike where the highest standing stocks of benthos had developed before fish moved into the area. Benthic abundance changed less from winter to summer in the planted areas, possibly because plants protected the benthos from predation and excessive temperatures.

68. The stomach contents of the most abundant fish indicated that both macrobenthos and meiobenthos were included in their diets. Smaller fish seemed to prefer meiobenthic harpacticoid copepods and larger fish preferred the macrobenthic polychaetes and isopods. Polychaete abundance was highest within the diked area while isopod abundance was highest in areas farthest from the dikes. The smaller meiobenthos were not censused concomitantly with the macrobenthos, but qualitative observations indicated the nematodes, harpacticoid copepods and ostracods were the most common major groups.

Summary and Conclusions

69. The fish communities in the study area before and after habitat development were similar with respect to species composition and relative abundance. This similarity may have occurred because of the delayed development of planted areas. The sandbag dike provided habitat diversity that may have attracted some fish in the otherwise homogeneous beach environment of Bolivar Peninsula. As the marsh within the diked area develops further, there should be more use by those fish species that frequent and depend upon marshes, such as killifishes and small minnows. During the beginning of the second growing season in June 1977, the site already provided heterogeneous habitats which tended to support greater use by fish and benthos than is generally associated with sandy shores along Bolivar Peninsula.

70. Increased protection from waves and subsequent entrapment of fine sediments by the dike accounted for much of the increased benthic abundance within the diked area. The presence of plants seemed to attract more insects. One year after construction the experimental habitat supported greater abundances of polychaetes and insects than the surrounding area. The abundance of isopods on the other hand, was much less within the diked area than outside. Polychaetes and isopods, along with harpacticoid copepods, were among the most important food items found in the stomachs of abundant fishes. The experimental habitat has the potential for providing greater trophic values and protection for valuable fish and wildlife than previously existed in the area.

PART VI: WILDLIFE

Methods and Materials

71. Bird, mammal, reptile, and amphibian use of the Bolivar Peninsula Habitat Development Site was examined between July 1976 and November 1977, with the objective of describing wildlife response to site development. The site initially chosen for habitat development was surveyed between September 1975 and March 1976 for baseline data.*

72. Baseline observations of wildlife composition and abundance were made using the methods described below. Bird species and abundance were recorded along transects sampled once a month. Presence of mammals was determined by use of monthly trapping sessions. Other vertebrates were identified by sightings and sign and terrestrial macroinvertebrates were collected by use of a sweep-net and household pesticide.

73. Vertebrates on the actual habitat development site were observed between July 1976 and November 1977. This represented an experimental period after site construction (grading, sandbag dike construction, fencing) and planting activities were almost or totally complete. Bird species and abundance were estimated twice a month from observation stations on transects traversing the intertidal and upland experimental areas and adjacent natural marsh and upland habitats (Figure 20). Bird population density and species diversity were determined by standard methods. Bird nesting was observed and recorded from nest searches during March through June 1977. Small mammals were live-trapped on grids in the upland experimental area and two adjacent natural areas outside the fence between September 1976 and August 1977. Large mammals were caught in live traps that were irregularly placed over the experimental area; they also were observed and/or recorded through sightings and identification of sign. Species of reptiles and amphibians were recorded when sighted. Further details of the methods

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* As noted earlier in the Introduction, the site was moved 305 m to the east after baseline samples were made.

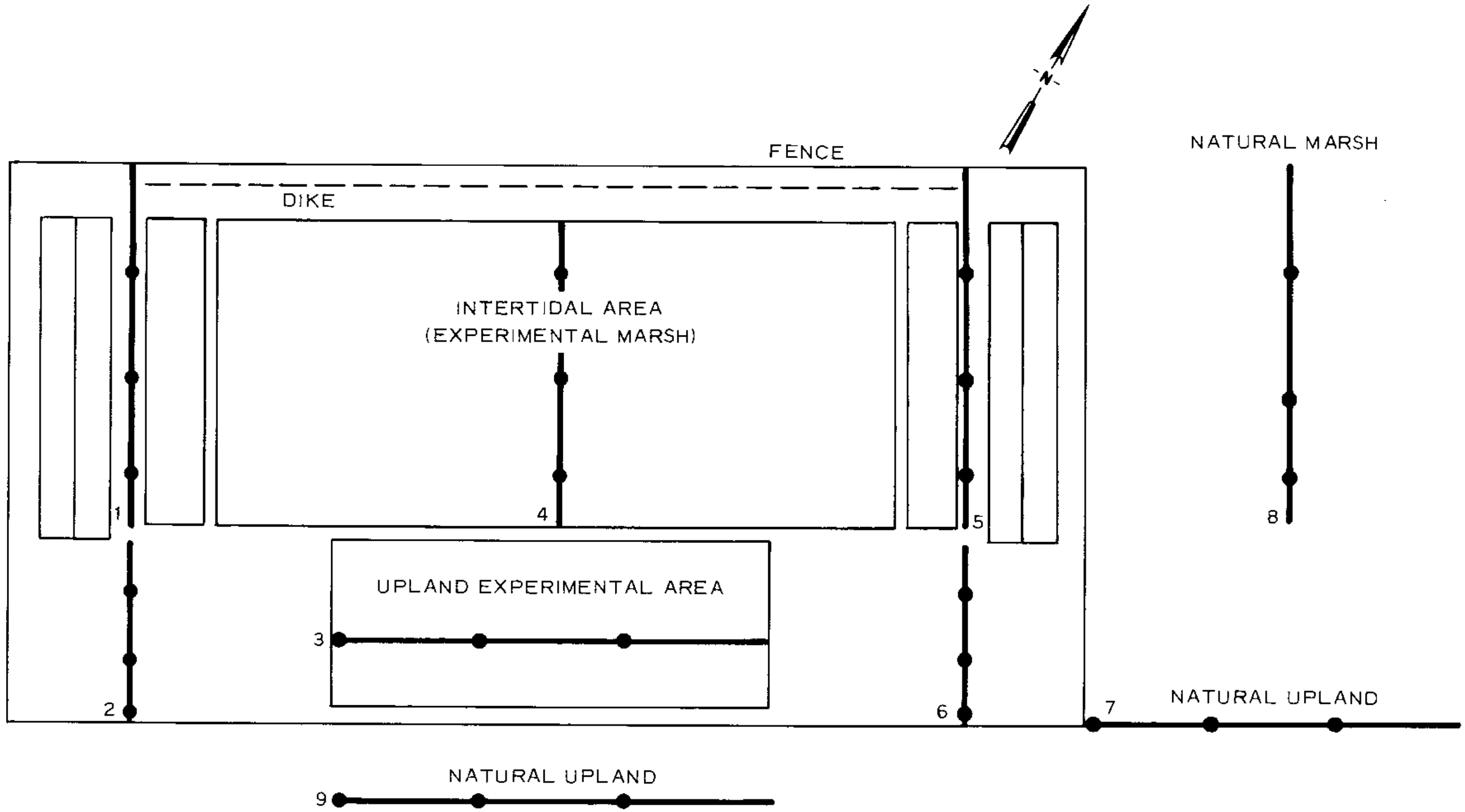

Figure 20. Location of bird transects in the experimental and natural areas, with observation stations indicated (●). Transects 2 and 6 were eliminated in March 1977

and locations of baseline areas and transects can be found in Dodd et al. (1978) for the baseline period and in Webb et al. (1978) for the experimental period.

Results and Discussion

Birds

74. The baseline study area yielded 98 species of birds. Permanent and wintering species were nearly equally represented (34 and 35, respectively) while there were only 20 migrants and 9 summer residents. Diversity was high, ranging from 2.81 in December 1975 to 3.98 in September 1975. Average number of species on the shoreline and marsh transects was 20.8 while 16.8 were represented on the upland transects. All the above results would undoubtedly have been modified if sampling had been performed over a twelve-month period.

75. Seventeen months of sampling on the actual study area yielded 135 bird species (Table 4). There were 71 species in common from the baseline area and the actual study area. Thirty-seven of the 135 bird species or 27.4 percent were migrants and recorded only in the spring; they contributed to the high densities and diversities recorded for that season (Figure 21). Data from summer and winter seasons showed lower numbers. Lowest diversity as expected, due to little vegetative cover, was observed in the fall of 1976.

76. Species numbers were consistently higher in the experimental marsh than in the natural marsh, but density was consistently less. There were no obvious trends in the upland areas. Thirteen species were recorded in densities greater than 3.00/ha including 11 species of shorebirds, laughing gulls, and red-winged blackbirds.

77. The least tern (*Sterna albifrons*) was the most prolific of the six species nesting on the study area in 1977, with 23 nests in the upland and four in the marsh sections, a density of 9.8/ha. Nest success was 61.5 percent based on 13 nests with complete data, and egg success was 65 percent, based on the known fate of 20 eggs. Clutch size averaged 1.74 with a total of 47 eggs. Hatching successes of

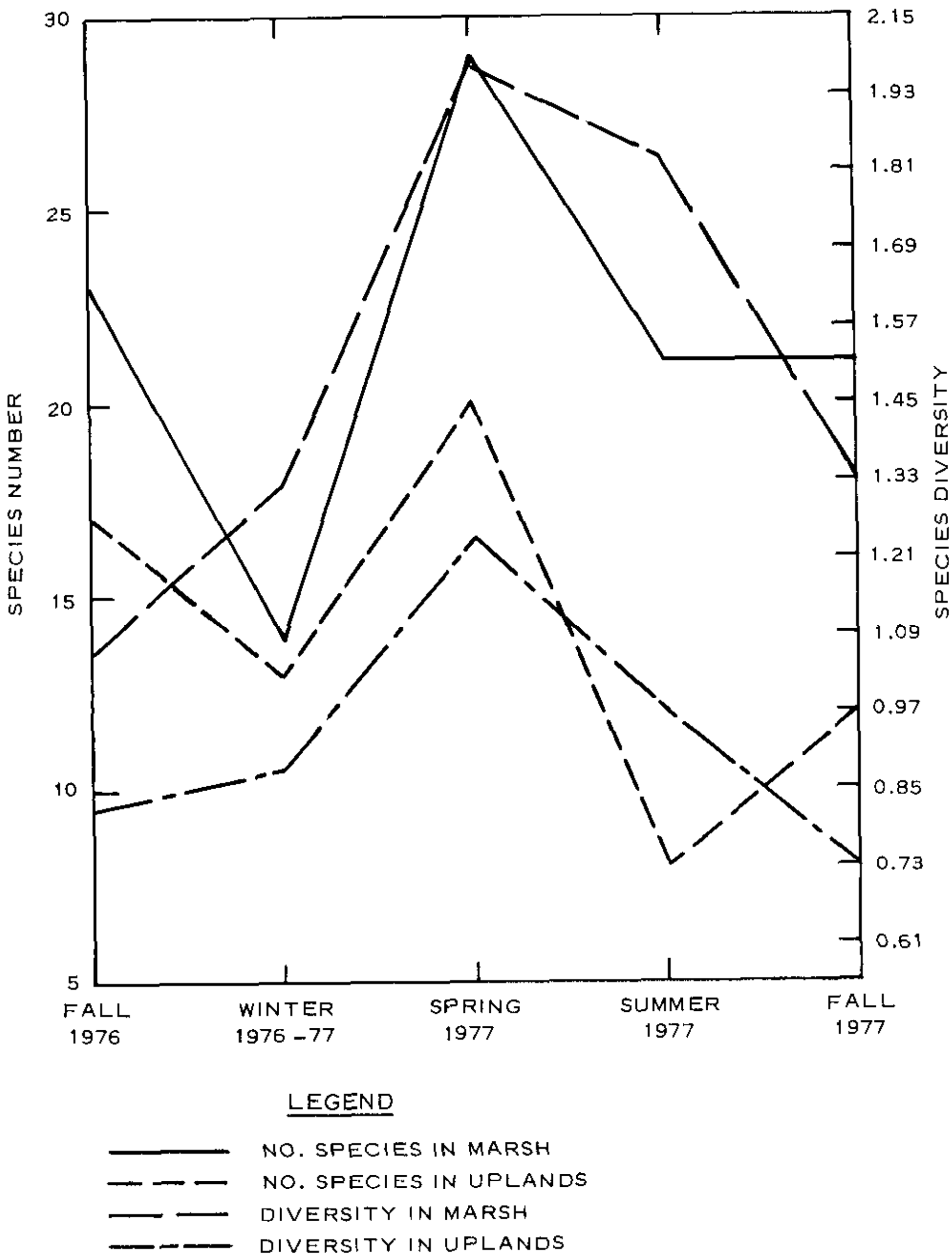

Figure 21. Bird species number and diversity, by season, for marsh and upland transects

79.2 percent and 56.3 percent were reported for the California least tern (Sterna albifrons browni) (Massey 1971, Swickard 1974). Nest success of terns in the experimental area is largely attributed to the fence, which excludes most predators and goats. A search of suitable habitat outside the fence revealed only one active nest (Webb et al. 1978).

78. Other species that nested in the experimental upland were Wilson's plover (Charadrius wilsonia) and killdeer (C. vociferus); in the experimental marsh, the brown-headed cowbird (Molothrus ater) and red-winged blackbird nested. No nests were found in adjacent natural marshes. The natural upland area had one nest of the scissor-tailed flycatcher (Muscivora forficata), and two each of the red-winged blackbird and brown-headed cowbird.

Mammals

79. Seventeen species were recorded during the baseline and experimental periods between September 1975 and September 1977 (Table 5). The fence prevented or discouraged five of those seventeen species from entering the experimental site.

80. Vegetation planted during the study appeared to attract three species. Eastern cottontails (Sylvilagus floridanus) were seen on the site in July 1976 and during almost all visits from January through August 1977. They grazed on both species of newly planted marsh grasses causing only slight permanent damage. When vegetation on the experimental site had become dense and tall enough to provide cover in the summer of 1977, the marsh rice rat (Oryzomys palustris) and hispid cotton rat (Sigmodon hispidus) were trapped for the first time. The cotton rat and the rice rat had been captured outside the fenced area since September 1976 and February 1977, respectively. One rice rat nest was found in the planted smooth cordgrass in July 1977.

81. The cotton rat was trapped heavily (88 individuals) outside the fenced area, with a tendency toward lower numbers in the winter and spring. This seasonal fluctuation has been recorded by Odum (1955) in Georgia, Layne (1974) in Florida, and Lee (1976) on Bolivar Peninsula.

Cotton rat presence also appeared to be related to availability of cover since the lowest number of captures (two) was made in February 1977, when cover was least. Both this observation and the sudden movement of the cotton rat into the vegetation of the fenced area agree with the work of Goertz (1964), who discussed the necessity of cover for the cotton rat. Details of cotton rat and house mouse (*Mus musculus*) populations from the baseline area and their reproductive states are given in Lee (1976).

Reptiles and amphibians

82. Fourteen species of reptiles and amphibians were sighted during the baseline and experimental periods between September 1975 and March 1977. Sightings declined during the experimental period, probably because of increased human activity. All reptiles and amphibians seen in the experimental site were in the upland area. Species lists can be found in Dodd et al. (1978) and Webb et al. (1978).

Summary and Conclusions

83. Wildlife use of the experimental site increased over the period of the study in response to growth of vegetation. This use was most obvious in the marsh. Shorebirds associated with marshes moved onto the site and increased in density, and two species of wetland-related mammals colonized the site. Seasonal variation in bird use was especially evident in the numbers of spring migrants recorded.

PART VII: OVERALL CONCLUSIONS AND RECOMMENDATIONS

84. Successful plantings of marsh grasses and upland plants were made at Bolivar Peninsula during 1976 and 1977. Even though the plants are still young and the site is not fully developed, results indicate that plants are providing habitat that is attracting fish and wildlife. Thus, habitat development on dredged material at Bolivar Peninsula is feasible. The investigation led to several salient conclusions and recommendations which are discussed below.

a. Habitat was developed at Bolivar Peninsula by providing protection to plants from physical forces such as wind and waves and protection from large animals such as goats. It is recommended that alternatives other than a sandbag dike be considered for cost effective, but satisfactory means of protecting a planted site from wind and waves in high energy areas, such as Bolivar Peninsula. Where practical, dredged material should be used to form a protective barrier for areas with intense wave energies. Fences should be constructed to protect the site if large grazing animals are present.

b. Results of this study indicated that smooth cordgrass and saltmeadow cordgrass are good marsh plants for marsh habitat development on dredged material in the Texas gulf coast area. Elevation was probably the most important factor at Bolivar Peninsula in determining the success of marsh grasses. In future habitat development efforts in this area, smooth cordgrass should be sprigged at elevations below mean high tide whereas saltmeadow cordgrass should be sprigged at elevations above mean high tide. Seeding should be used only to augment sprigging and fertilization does not appear necessary.

c. Several upland plant species of grasses, shrubs, and trees survived from plantings at Bolivar Peninsula. Plants appearing to have good survival and growth potential on upland dredged material sites in the Texas gulf coast area are: live oak, winged sumac, wax myrtle, bitter panic grass, and coastal bermuda grass. Results from this study tentatively indicate that fertilization of upland plants generally has a beneficial effect on planting success; however, observations over a longer time period are needed to confirm this effect.

d. Termination of the project eliminated observations of aquatic biota at a time when the marsh was just becoming developed. Preliminary observations indicate that marsh development is associated with increases in benthic organisms as well as increases in insect and fish activity. Bird diversity and activity in the planted marsh also have increased. Thus, the developing habitat started by planting marsh grasses is likely to provide an area of greater resource value to fish and wildlife than previously existed on the sandy dredged material. Limited observations will be made in the future to document the expected increase in the use of the marsh by birds and aquatic organisms.

e. The plants in the upland habitat area, like the plants in the marsh area are young and have not achieved their full potential for providing food and cover for wildlife. However, the important point is that these plants have survived and are spreading. The upland area has already received nesting activity from five breeding bird species in the area and is expected to attract even more bird activity as well as more individuals and species of small mammals. If the fence were removed, larger mammals such as the raccoon, swamp rabbit, and opossum probably would use the site, but trampling and grazing by goats would jeopardize the successful development of the plants. The fence has caused some animals to seek the site's protection. For example, least terns have used the sight for nesting as opposed to areas outside the fence.

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Table 1

Project Costs

Cost Category	Approximate Unit Costs	Total
I. Plans and Specifications for Site Acquisition and Construction		
A. Topographic surveys		$ 7,000.00
B. Soil sampling and testing		22,000.00
C. Site layout, dike design, and other pre-development operations		14,700.00
D. Site acquisition		1,300.00
TOTAL		$ 45,000.00
II. Site Construction and Post-Construction		
A. Earthmoving, grading and other land preparation activities	$7,967/ha	$ 58,033.00
B. Sand bag construction and maintenance	$ 348/m	184,900.00
C. Fence construction	$ 16/m	19,052.00
D. Other costs (mobilization, demobilization, logistical support, dike and topographic surveys)		26,000.00
TOTAL		$287,985.00
GRAND TOTAL		$332,985.00

Table 2

Fertilizer Treatments Applied to the Thirty Plots within One Elevation Block of the Intertidal Monotypic Plot Experiment

Plot No.	Fertilizer Treatment*	Species	Method**
1	F_0	smooth cordgrass	sprig
2	F_0	smooth cordgrass	seed
3	F_0	saltmeadow cordgrass	sprig
4	F_0	saltmeadow cordgrass	seed
5	F_0	no planting	none
6	F_0	no planting	none
7	F_1	smooth cordgrass	sprig
8	F_1	smooth cordgrass	seed
9	F_1	saltmeadow cordgrass	sprig
10	F_1	saltmeadow cordgrass	seed
11	F_1	no planting	none
12	F_1	no planting	none
13	F_2	smooth cordgrass	sprig
14	F_2	smooth cordgrass	seed
15	F_2	saltmeadow cordgrass	sprig
16	F_2	saltmeadow cordgrass	seed
17	F_2	no planting	none
18	F_2	no planting	none

(Continued)

* The types of fertilizer treatment were:

F_0: no fertilizer

F_1: low rate, 122 kg N/ha, 122 kg P_2O_5/ha, and 122 kg K_2O/ha (122 g/m^2)

F_2: high rate, 244 kg N/ha, 244 kg/P_2O_5/ha, and 244 kg K_2O/ha (244 g/m^2)

F_3: split application, low rate

F_4: split application, high rate

** Seeding was accomplished in March 1977 on 30 sq m plots.

Table 2 (Concluded)

Plot No.	Fertilizer Treatment*	Species	Method**
19	F_3	smooth cordgrass	sprig
20	F_3	smooth cordgrass	seed
21	F_3	saltmeadow cordgrass	sprig
22	F_3	saltmeadow cordgrass	seed
23	F_3	no planting	none
24	F_3	no planting	none
25	F_4	smooth cordgrass	sprig
26	F_4	smooth cordgrass	seed
27	F_4	saltmeadow cordgrass	sprig
28	F_4	saltmeadow cordgrass	seed
29	F_4	no planting	none
30	F_4	no planting	none

Table 3

Fertilizer Treatment Design for Upland Experiments

Plant Type and Tier	Row	Species	Random Fertilizer Treatment of Subplots* Replicate 1	Replicate 2	Replicate 3
Grasses, lower tier	1	bitter panicum	F_0 F_1 F_2	F_1 F_2 F_0	F_2 F_0 F_1
	2	coastal bermuda	F_1 F_2 F_0	F_2 F_0 F_1	F_1 F_2 F_0
	3	bluestem	F_2 F_0 F_1	F_0 F_1 F_2	F_0 F_1 F_2
	4	No planting	F_1 F_2 F_0	F_0 F_2 F_1	F_2 F_0 F_1
Shrubs, middle tier	1	gulf croton	F_1 F_2 F_0	F_0 F_1 F_2	F_2 F_1 F_0
	2	wax myrtle	F_0 F_1 F_2	F_2 F_1 F_0	F_2 F_0 F_1
	3	winged sumac	F_0 F_1 F_2	F_0 F_2 F_1	F_1 F_0 F_2
	4	No planting	F_2 F_0 F_1	F_1 F_0 F_2	F_0 F_2 F_1
Trees, upper tier	1	salt cedar	F_2 F_1 F_0	F_1 F_0 F_2	F_1 F_2 F_0
	2	No planting	F_1 F_2 F_0	F_0 F_2 F_1	F_1 F_0 F_2
	3	sand pine	F_0 F_1 F_2	F_1 F_2 F_0	F_0 F_1 F_2
	4	live oak	F_0 F_2 F_1	F_2 F_1 F_0	F_2 F_0 F_1

* Treatments consisted of: F_0 - no fertilizer applied;

F_1 - low rate, 25 kg N/ha applied initially with 50 kg P_2O_5/ha, and 40 kg K_2O/ha, 100 kg N/ha applied 1 month later;

F_2 - high rate, 25 kg N/ha applied initially with 100 kg P_2O_5/ha, and 80 kg K_2O/ha, 200 kg N/ha applied 1 month later;

Table 4

Seasonal Occurrence of Birds at Bolivar Peninsula

Common Name	Scientific Name	Occurrence By Season: Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Eared grebe	*Podiceps nigricollis*			X		
White pelican	*Pelecanus erythrorhynchos*	X		X		
Double-crested cormorant	*Phalacrocorax auritus*	X				X
Olivaceous cormorant	*Phalacrocorax olivaceus*				X	X
Magnificant frigatebird	*Fregata magnificens*	X			X	
Great blue heron	*Ardea herodias*	X	X	X		X
Green heron	*Butorides striatus*			X		
Cattle egret	*Bubulcus ibis*			X		
Reddish egret	*Dichromanassa rufescens*	X	X	X		X
Great egret	*Casmerodius albus*	X	X	X	X	X
Snowy egret	*Egretta thula*	X	X	X	X	X
Louisiana heron	*Hydranassa tricolor*	X		X	X	X
Black-crowned night heron	*Nycticorax nycticorax*	X				
White-faced ibis	*Plegadis chihi*	X		X		X
White ibis	*Eudocimus albus*	X		X	X	X
Roseate spoonbill	*Ajaia ajaja*	X	X	X	X	X
Snow goose	*Chen caerulescens*	X				
Mottled duck	*Anas fulvigula*					X
Blue-winged teal	*Anas discors*	X	X	X		
Northern shoveler	*Anas clypeata*			X		
Canvasback	*Aythya valisineria*		X			
Red-breasted merganser	*Mergus serrator*		X			
White-tailed kite	*Elanus leucurus*	X	X			
Red-tailed hawk	*Buteo jamaicensis*	X				
Marsh hawk	*Circus cyaneus*	X	X		X	X

(Continued)

Table 4 (Continued)

Common Name	Scientific Name	Occurrence By Season				
		Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Osprey	*Pandion haliaetus*	X	X			
American kestrel	*Falco sparverius*	X				X
Clapper rail	*Rallus longirostris*	X		X		X
American coot	*Fulica americana*	X				
American oystercatcher	*Haematopus palliatus*	X	X			
Semipalmated plover	*Charadrius semipalmatus*	X	X	X	X	X
Piping plover	*Charadrius melodus*	X	X	X		X
Wilson's plover	*Charadrius wilsonia*	X		X	X	X
Killdeer	*Charadrius vociferus*	X	X	X	X	X
Black-bellied plover	*Pluvialis squatarola*	X	X	X	X	X
Ruddy turnstone	*Arenarius interpres*	X	X	X	X	X
Long-billed curlew	*Numenius americanus*	X	X	X		X
Whimbrel	*Numenius phaeopus*			X		
Spotted sandpiper	*Actitis macularia*	X	X	X	X	X
Solitary sandpiper	*Tringa solitaria*			X		
Willet	*Catoptrophorus semipalmatus*	X	X	X	X	X
Greater yellowlegs	*Tringa melanoleucus*	X	X	X		X
Lesser yellowlegs	*Tringa flavipes*		X	X		
Red knot	*Calidris canutus*					
Pectoral sandpiper	*Calidris melanotos*			X		
White-rumped sandpiper	*Calidris fuscicollis*			X		
Least sandpiper	*Calidris minutilla*	X	X	X	X	X
Dunlin	*Calidris alpina*	X	X	X		X
Semipalmated sandpiper	*Calidris pusillus*			X	X	
Western sandpiper	*Calidris mauri*	X	X	X		X

(Continued)

Table 4 (Continued)

Common Name	Scientific Name	Occurrence By Season Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Sanderling	*Calidris alba*	X	X	X	X	X
Dowitcher	*Limnodromus sp.*	X	X	X	X	X
Marbled godwit	*Limosa fedoa*					X
American avocet	*Recurvirostra americana*	X	X			
Black-necked stilt	*Himantopus mexicanus*	X		X		X
Herring gull	*Larus argentatus*	X	X			X
Ring-billed gull	*Larus delawarensis*	X	X	X		X
Laughing gull	*Larus atricilla*	X	X	X	X	X
Gull-billed tern	*Gelochelidon nilotica*			X		
Forster's tern	*Sterna forsteri*		X	X	X	X
Least tern	*Sterna albifrons*	X		X	X	X
Royal tern	*Sterna maxima*	X	X		X	X
Caspian tern	*Sterna caspia*			X	X	X
Sandwich tern	*Sterna sandvicensis*	X			X	X
Black tern	*Chlidonias niger*	X			X	X
Black skimmer	*Rynchops niger*	X		X	X	X
Mourning dove	*Zenaida macroura*	X	X	X		X
Yellow-billed cuckoo	*Coccyzus americanus*	X		X		X
Short-eared owl	*Asio flammeus*		X			
Common nighthawk	*Chordeiles minor*	X		X	X	X
Chimney swift	*Chaetura pelagica*			X		
Ruby-throated hummingbird	*Archilochus colubris*			X		X
Belted kingfisher	*Megaceryle alcyon*	X				X
Common flicker	*Colaptes auratus*		X			X
Eastern kingbird	*Tyrannus tyrannus*	X		X	X	X

(Continued)

Table 4 (Continued)

Common Name	Scientific Name	Occurrence By Season				
		Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Scissor-tailed flycatcher	*Muscivora forficata*	X		X	X	X
Eastern phoebe	*Sayornis phoebe*			X		
Eastern wood pewee	*Contopus virens*	X				
Horned lark	*Eremophila alpestris*	X	X	X	X	X
Tree swallow	*Iridoprocne bicolor*			X		
Bank swallow	*Riparia riparia*			X		
Rough-winged swallow	*Stelgidopteryx ruficollis*	X		X		X
Barn swallow	*Hirundo rustica*	X		X	X	X
Purple martin	*Progne subis*			X	X	
Blue jay	*Cyanocitta cristata*	X				
House wren	*Troglodytes aedon*	X				X
Short-billed marsh wren	*Cistothorus platensis*					X
Mockingbird	*Mimus polyglottos*			X		X
Gray catbird	*Dumetella carolinensis*			X		
American robin	*Turdus migratorius*		X			
Hermit thrush	*Catharus guttatus*	X				
Swainson's thrush	*Catharus ustulatus*			X		
Veery	*Catharus fuscescens*			X		
Blue-gray gnatcatcher	*Polioptila caerulea*	X				X
Ruby-crowned kinglet	*Regulus calendula*	X	X			
Water pipit	*Anthus spinoletta*	X	X	X		
Loggerhead shrike	*Lanius ludovicianus*	X	X		X	X
White-eyed vireo	*Vireo griseus*			X		
Red-eyed vireo	*Vireo olivaceus*			X		
Black-and-white warbler	*Mniotilta varia*			X		

(Continued)

Table 4 (Continued)

Common Name	Scientific Name	Occurrence By Season: Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Prothonotary warbler	*Protonotaria citrea*			X		
Worm-eating warbler	*Helmitheros vermivorus*			X		
Tennessee warbler	*Vermivora peregrina*			X		
Orange-crowned warbler	*Vermivora celata*			X		
Yellow warbler	*Dendroica petechia*			X		
Magnolia warbler	*Dendroica magnolia*			X		
Yellow-rumped warbler	*Dendroica coronata*	X	X	X		X
Black-throated green warbler	*Dendroica virens*			X		
Yellow-throated warbler	*Dendroica dominica*			X		
Blackpoll warbler	*Dendroica striata*			X		
Palm warbler	*Dendroica palmarum*					X
Ovenbird	*Seiurus aurocapillus*			X		
Northern waterthrush	*Seiurus noveboracensis*			X		
Common yellowthroat	*Geothlypis trichas*			X		
Yellow-breasted chat	*Icteria virens*			X		
Hooded warbler	*Wilsonia citrina*			X		X
American redstart	*Setophaga ruticilla*			X		
Eastern meadowlark	*Sturnella magna*	X	X			X
Red-winged blackbird	*Agelaius phoeniceus*	X	X	X	X	X
Orchard oriole	*Icterus spurius*	X				X
Northern oriole	*Icterus galbula*			X		X
Great-tailed grackle	*Quiscalus mexicanus*	X		X		X
Common grackle	*Quiscalus quiscula*	X			X	X
Brown-headed cowbird	*Molothrus ater*			X	X	
Cardinal	*Cardinalis cardinalis*			X		

(Continued)

Table 4 (Concluded)

Common Name	Scientific Name	Occurrence By Season Fall 76	Winter 76-7	Spring 77	Summer 77	Fall 77
Rose-breasted grosbeak	*Pheucticus ludovicianus*			X		
Blue grosbeak	*Guiraca caerulea*			X		
Indigo bunting	*Passerina cyanea*			X		
Painted bunting	*Passerina ciris*	X				
Ipswich sparrow	*Passerculus sandwichensis*	X	X	X		
LeConte's sparrow	*Ammospiza leconteii*					X
White-winged junco	*Junco hyemalis*	X	X			
Field sparrow	*Spizella pusilla*	X				
Swamp sparrow	*Melospiza georgiana*					X
Song sparrow	*Melospiza melodia*	X	X			X
	Total	75	47	91	37	69

Note: Taxonomy is according to American Ornithologists' Union (1957, 1973, and 1976).

Table 5

Mammal Species Noted in Bolivar Peninsula Baseline and Study Areas, with Their Abundance

Common Name	Scientific Name	Abundance in Baseline Area*	Abundance in Study Area*	Comments
Opossum	*Didelphis virginiana*	Common	Rare	Largely excluded from fenced area
Short-tailed shrew	*Blarina brevicauda*	Rare	Not observed	
Nine-banded armadillo	*Dasypus novemcinctus*	Very common	Rare	Largely excluded from fenced area
Eastern cottontail	*Sylvilagus floridanus*	Rare	Very common	Attracted to planted vegetation
Swamp rabbit	*Sylvilagus aquaticus*	Very common	Rare	
Marsh rice rat**	*Oryzomys palustris*	Not observed	Rare	Remained outside fence until vegetation developed
Hispid cotton rat**†	*Sigmodon hispidus*	Very common	Very common	Remained outside fence until vegetation developed
Norway rat**	*Rattus norvegicus*	Not observed	Rare	Introduced with humans and equipment
House mouse**†	*Mus musculus*	Common	Common	
Nutria	*Myocastor coypus*	Rare	Rare	
Raccoon	*Procyon lotor*	Very common	Common	
Eastern spotted skunk	*Spilogale putorius*	Rare	Not observed	
River otter	*Lutra canadensis*	Not observed	Rare	Attracted to fish and invertebrates around dike
Bobcat	*Felis rufus*	Rare	Not observed	
Cow	*Bos indicus*	Common	Common	Excluded from fenced area
Goat	*Capra hircus*	Very common	Very common	Excluded from fenced area
Sheep	*Ovis aries*	Common	Common	Excluded from fenced area

* Rare = seen one to two times.
Common = seen often.
Very common = seen on most or all visits.
** Trapped in study area.
† Trapped in baseline area.

Notes: 1. No federally designated endangered or threatened animal species were seen. The State of Texas protects one species observed, the nutria (*Myocaster coypus*).
2. Taxonomy is according to Jones et al. 1975.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Allen, Hollis H

Habitat development field investigations, Bolivar Peninsula marsh and upland habitat development site, Galveston Bay, Texas; summary report / by Hollis H. Allen ... [et al.]. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

75 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-78-15)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under DMRP Work Unit No. 4A13K.

Appendix D published separately.

Appendices A-C on microfiche in pocket.

References: p. 61-64.

1. Bolivar Peninsula. 2. Dredged material disposal. 3. Environmental effects. 4. Field investigations. 5. Habitat development. 6. Habitats. 7. Marsh development. 8. Vegetation establishment. 9. Waste disposal sites. I. United States. Army. Corps of Engineers. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-15.

TA7.W34 no.D-78-15